# RECLAMATION OF COSTAL SAND DUNES IN EUROPE AND IN EASTERN UNITED STATES

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Francis Grant Schleicher B. S.
1917

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# RECLAMATION OF COASTAL SAND DUNES
# in
# EUROPE AND IN EASTERN UNITED STATES

(A report prepared as part of the requirements of work in minor field of graduate study)

by

Francis Grant Schleicher, B.S.

May 31, 1917.

C.T

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# Reclamation of Sand Dunes

## Introduction

With the increase of population the demand for more land for agricultural purposes has become more and more important. Part of this demand can be met by more intensive cultivation but the larger part must be met by the reclamation of hitherto uncultivable lands. Such lands as extensive swamps, arid deserts, exposed, rocky mountain lands, and sand dune areas can hardly be reclaimed by private endeavor. The chief factor barring private enterprise is the shortness of such endeavors. It is only the state that can work at reclaiming areas where constant supervision and even perpetual work is needed to hold the forces of nature in check. Government enterprise has recovered the flooded lowlands of Holland, the marshes of Scotland, portions of the arid deserts of the Western United States, the deserts of Hungary, the exposed slopes of the French Alps and the sand dune areas of Gascogne. This, after all private work had failed.

The reclamation of sand dune areas has always been one of great importance. Immense areas of once fertile land have been devastated and depopulated by the encroachment of moving sands. The economic destructiveness of these sands has not been confined to those areas where they are constantly in motion but has even threatened and destroyed large forests, fertile, agricultural regions and river channels that are most important.

Where these sands have been fixed the work has been found to be a paying investment. The revenues derived from the forests on these lands, the value of the land for recreation and the security of certain river channels have paid many times over the work necessary to fix these dune areas.

In the development of this subject the methods used in Europe will be reviewed first, since it is European practices that have been followed in reclaiming our own sand dune areas.

## Reclamation of Sand Dune Areas in Europe

The sand dune area of Europe is, according to Wessely*, divided into the following districts :

1. The German lowlands which extend from Holland along the North Sea and along the Baltic to Russia.
2. The Danish-German islands which lie off Schleswig-Holstein and Danish-Jutland.
3. The sand dune areas of Austria Hungary, especially along the banks of the Donau and in the Banat region.
4. The French, "Landes" of Gascogne.
5. The seashore dunes of Holland, Belgium, Denmark, North Germany, Russia and the west coast of France.
6. The Baltic shores of Russia.

In order to fully cover these regions the methods used in reclaiming dune areas typical of the various sections will be fully discussed.

The general methods used in reclaiming the "Landes" are typical of methods used in the other regions except for modifications determined by local conditions. The methods used in Jutland are typical of those used in Denmark, Germany and Holland along the shore bordering the North Sea and Baltic. The methods used in Belgium are typical of those used on the channel section of France and these methods will be discussed in detail under their respective sections.

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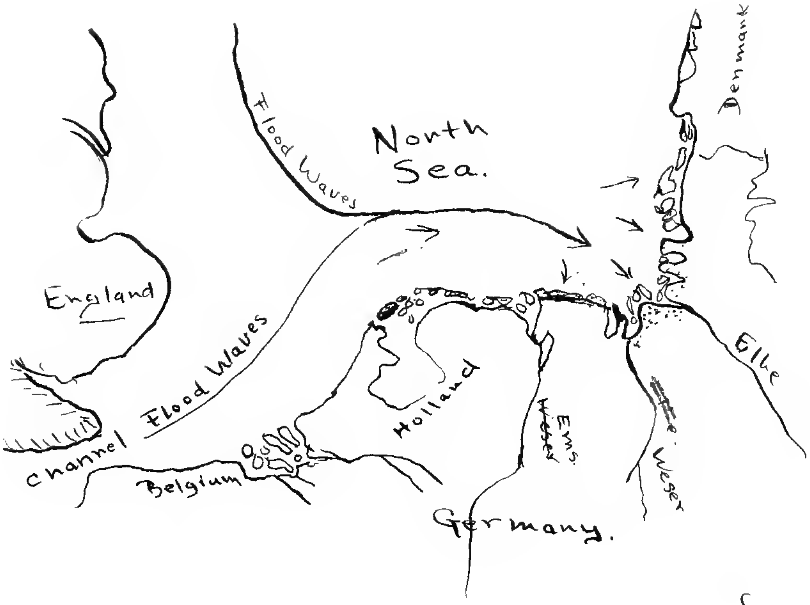
*"Der Europäische Flugsand und seine Kultur," Josef Wessely, Wien, 1873.



North Sea Section of Germany. (also Holland)

Showing the direction of the prevailing Flood Waves.

Follows page 3.

Fig 2.

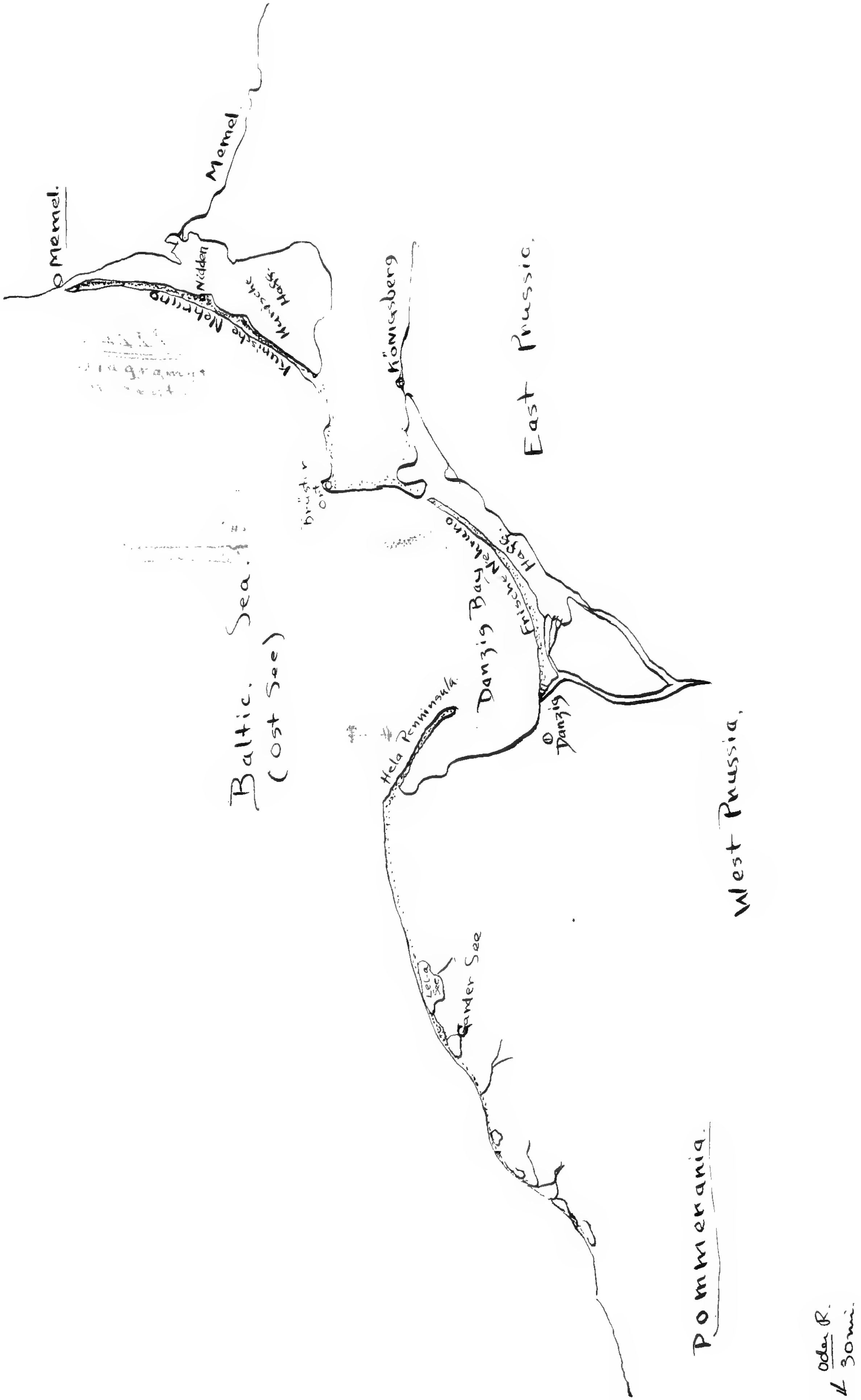

Memel.
Memel
Nidden
Kurische Haff
Kurische Nehrung
Königsberg
East Prussia
Brüster Ort
Haff
Frische Nehrung
Danzig Bay
Baltic Sea
(Ost See)
Hela Penninsula
Danzig
West Prussia
Leba See
Garder See
Pommerania
Oder R.
30 mi.

Fig 3.

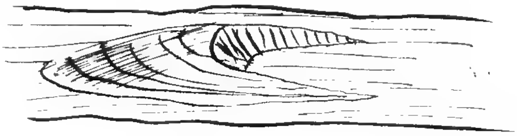
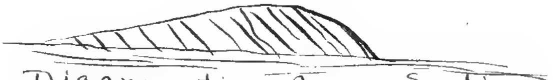
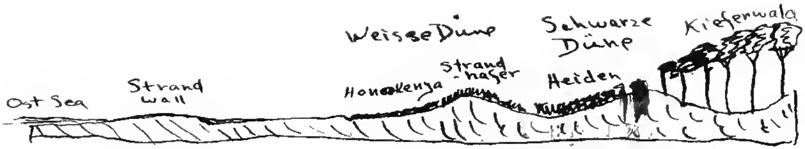


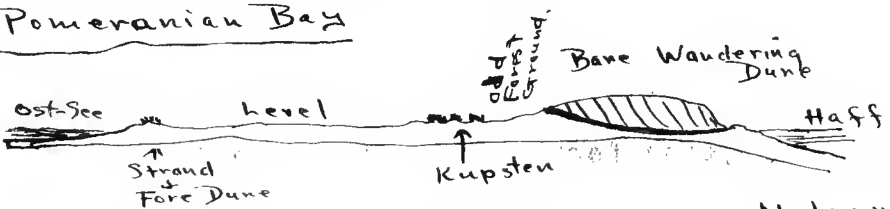
Diagram of Sickle-shaped Dune
Direction of Wind →



Diagramatic Cross-Section
on center of the same Dune



Diagrammatic Cross-section of
the "Nehrung at Misdroy on the
Pomeranian Bay



Cross-section of the Kurische Nehrung
at Nidden

Diagrams from Solger's "Dünenbuch."

precedes page 4.

## Germany

The dune areas of Germany* occur chiefly on the shores of Mecklenburg, Brandenburg, Pommern, Posen and Prussia. The characteristics of this section are similar to those of Friesland and Holland. The chief dune areas are, between the mouths of the Elbe and the Oder, and along the Kurische and Frische Nehrung.

The methods of reforestation of the dune areas were early worked out on an organized basis. The methods used were similar to those used on the "Dunes of Gascony". Fore dunes were first built up and planted and the land in the lee forested. The chief differences were in the character of the plants used in this work.# According to Hitchcock,** the dunes were controlled by plantings of "beach grass and sand hedges and the trees used were, Pinus montana, laricio, austriaca, and sylvestris". A study of the cross-sections of the Nehrung at Misdroy# and the Nehrung at Nidden will illustrate clearly the manner in which this problem was handled.

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*Josef Wessely "Der Europäische Flugsand", Wien, 1873.

**A.S. Hitchcock, U.S.D.A. in the Nat. Geog. Magazine, 1904, page 43.

# "Dünenbuch#, Dr. F.E. Solger, Stuttgart, 1910.

The plants used in this work were, Honckenya peploides, Ammophila arenaria, Hordeum arenarium, Eryngium martimium, the heather, the willows and the pines.

In Germany the attitude of the people has made reclamation work easy. The communities especially have aided the government in a whole hearted manner. In Prussia the land of the North German lowlands are largely held by large land owners. The initial attempt at reclamation work on the dunes were first made but the work was not done on a large scale until the government aided them. The latter made sufficient appropriations and laws to make the work of a permanent nature.

The government took title to all the fore dune areas and placed them under a spearate administration of officers and dune guards. The former have charge of the enforcement of the dune laws, planting plans, and administrative work, while the latter watch the dunes and report any breaks in the cover etc. If this occurs the local communities send men to repair the dune and replant it. Violation of the dune laws are punished severely, any infractions being considered a "criminal" act. No one is allowed to graze any stock on this land or on the land immediately in the rear of the dune area. Trespassing is also prohibited as is also the removing of plants or the digging of the soil. In order to give proper notice the area is marked by large boundary pillars upon which printed warnings are posted.

The problem of the reclamation of dune lands in

Germany is well under way and the success of the work is well assured. Some of the dune plantations* are considered a standard for such work

## **Fixation of the Dunes on the Coast of Jutland, Denmark***.

Along the west coast of Jutland there were once forests of pine and spruce. These forests were recklessly exploited and the result was a maked coast with seriously depleted interior forests. The west winds then swept unobstructed across the peninsula and dried out the soil, sweeping away the humus and exposing the mineral soil.

The impoverished soil could then support nothing but heather which producing an acid humus, caused an underlying hard-pan to form. The worst consequences resulted near the coast. Here the sand was carried back three and even four miles and wherever obstructions occurred a sand dune was gradually formed by the sand accumulation. This was done partly by the action of sand grasses which holding the sand in place caused these mounds to grow even larger. These dunes at last reached a size where the wind was too strong for the grasses and moving dunes were formed which engulfed villages, churches, etc., and buried large areas of fertile land.

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*The plantations on the Kurische Nebrung are considered a standard for such work. See plates in the Nat. Geog. Mag. 1904, p. 46.

**Fixation of Dunes on the Coast of Jutland", W.H. Morrill, For. Quarterly IX, No. 1, p. 62 ff.

***Die Forst Kultur in Jütland, p. 167 - Aus dem Walde, 1879, H. Burkhardt.

From 1792 on, attempts were made in a more or less unorganized way to overcome these dunes by planting beach grass on them. It was not until 1857 that the government realized that the planting of woody growth was necessary to fix the dunes after the beach grass had done its best work.

In 1870 the Dune Department which had been formed in 1867 had gained enough experience to go at things in an organized manner. It had by this time determined what trees were able to withstand strong, salt winds, a vigorous climate, and the light soil. With experience came also a saving in the cost of methods. For example in 1853 the cost per acre for the formation of a plantation was $70 and in 1878 it was $30.

The methods used were as follows :

Heather was first planted in all the low spots and the tops of high hills were removed to prevent strong winds. The heather holds the sand in place until the beach grass can take root. Ordinarily the beach grass was planted on the east slope in rows parallel to the prevailing west wind. The wind cuts off the tops of hills with more than a $30^{\circ}$ slope and sifts the sand over the grassy, east aspect where the beach grass grows and holds this sand in place.

The beach grass is planted, three or four in a hole, 8" to 10" deep, made with a special spade. The distance between the holes is 6 inches to 9 inches and the rows are 12 inches apart.

Hedges, brush and barriers at water level are used to help hold the sand and prevent the sand from accumulating too rapidly. The hedges form an embankment covered with beach

grass at the water's edge. To protect this barrier a set of hedges are run out in the water to protect the shore barrier from erosion. The latter hedges are placed 7 yards apart and the depth is only 4½ feet, and 1 foot wide. This acts as a buffer to the waves. The cost of these hedges runs about 40¢ a running yard.

The tree species best adapted to dune planting are: Pinus montana and Picea alba of which 3 and 4 year transplants are used. The latter thrives close to the beach where the salt air would harm most species. Abies pectinata thrives well on the north slopes of the dunes and in deep depressions. The greater part of the dune is planted with Pinus montana especially on the west slopes. The planting is done in rows 12 feet apart and 6 feet between the plants.

Experiments with every evidence of success have been made with Quercus pedunculata and sessiliflora, Fraxinus excelsior, Betula alba and Alnus glutinosa upon moist ground. Fagus silvatica has been used on high places.

The success of this work shows that ultimately the southwestern part of Jutland will become forested once the west coast has a complete forest belt to protect the interior. The evil caused by previous generations will be eventually corrected.

## Dunes of Holland*

The dunes of Holland are very similar to those of the

*"Dikes of Holland" G.H. Matthes, U.S.G.S. - from an article in the National Geog. Mag. # 12, 1901, p. 219.

North Sea Coast. They occur principally about the mouth of the Rhine and at Katwyk and also near Domburg in the Province of Zealand. The latter are well under control, the problem of fixing the moving sands having been undertaken at an early date. The dunes of the Rhine have migrated east a distance of two miles in about eighteen centuries. In other places this movement has been about six to seven miles in the same time.

The movement of these dunes has been permanently stopped by the planting of a grass (Arundo arenacea), or "helm", on the seaward side of the dune. The grass is planted by hand in tufts not quite two feet apart aligned in rows. The grass penetrates the sand with its long roots and holds it in place. This planting was done over a chain of dunes in Holland of two hundred miles and varying in width of 400 yards to 3 miles. The elevation ranges from 60 - 200 feet above sea level. In other places the forest growth has been started on dunes further inland with gratifying results.

## Belgium*

Sand dunes are found on nearly the whole Belgium coast. In the neighborhood of Nieuport the dunes are nearly 1 mile in width and generally vary in height from 50 to 80 feet although in one place they are 114 feet high. Towards Ostend the dunes diminish in height, and almost disappear at Maria - Kirke. Between Maria-Kirke and Ostend they are about 500 feet wide. Northward of Heyst they are about 900 feet wide, and on the west side of the Scheldt, about three-quarters of a mile wide and from 50 - 80 feet high.

*Case, G.O. 1914 "Coast Sand Dunes, etc."

Coast sand dunes in Belgium are usually fixed by means of marram grass and the "argoussier". The marram grass is planted in tufts of 15 or 20 stems in quincunx order about 15 inches apart. March, April, and November are found to be the best months for planting. The "argoussier" is indigenous to Belgium and is a shrub with silver leaves. It is used to make hedges on the flanks of the dunes and in exposed places where it can stop the drift of the sand.

The dunes at Maria-Kirke and Middle-Kirke are protected by a sea wall on top of which is a roadway. The shore is also protected by a long series of Case groynes.

It is stated that conifers have not grown satisfactorily on this coast so other trees have been planted. Plantations of ash, elder, balsam, birch, dwarf willow, maple and various species of pine have been found the most successful and are now used.

## France*

The dune area of France is divided between the Atlantic Coast line and the Channel coast line. The damage done by the latter and the area covered is relatively small and has been easily taken care of. The former area bordering

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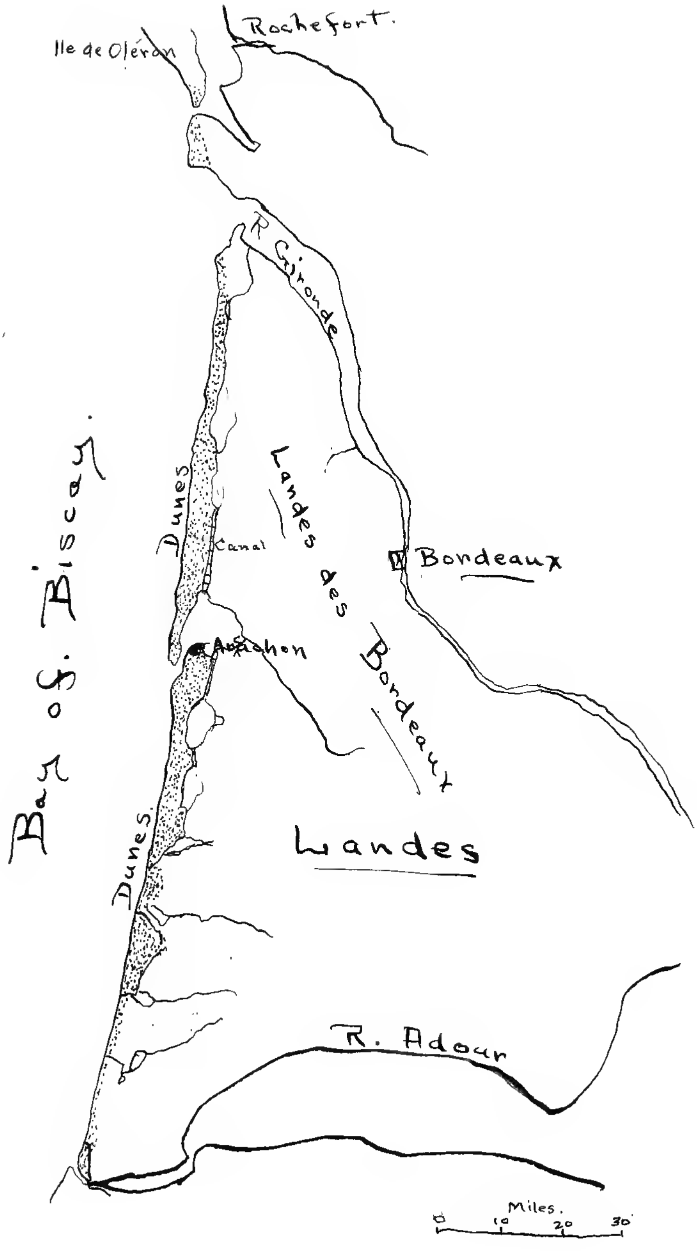
*"Land and Dunes of Gascony", by Collier Cobb in "Journal of the Elisha Mitchell Society, 1910.

Fig 4.



Landes and Dunes of Gascony. – Collier Cobb

Follows p. 10.

on the Bay of Biscay is best known as the "Landes des Gascogne". It is the reclamation of the dunes of this area that set the standard and methods for all subsequent work.

### "Landes and Dunes of Gascony"

The best works on the Dunes of Gascony are: "Les Landes des Gascogne", by M. Chambrelent, and "Les Landes et Les Dunes de Gascogne", by M. Grandjean.

In the early part of this century, previous to 1857, the condition of this flat triangular plain, known as the "Landes", which is roughly bounded by the Bay of Biscay, the river Adour, and the river Garonne, and the Medoc, was in brief as follows: "There were miles of marshy and almost treeless wastes, covered mainly with a low, dense growth of herbage. It was wet, unhealthy and sparsely settled. The few people who lived there depended on their flocks. These the shepherds took care of while on high stilts which enabled them to easily cross the wet ground. Their spare time was spent in knitting stockings. The conditions of the "Landes" was due to immense sand dunes which arrayed themselves along the shore of the Bay of Biscay. They moved inland, covered villages and occluded inlets. The damage done by these moving sand dunes so increased that the government officials studied the work, and devised and executed plans, and now, thanks to de Villers, Chambrelent and Bremontier, the pioneer workers, the "Dunes and Landes", are covered with a beautiful growth of maritime pine. The region is now famous as a health resort, combining the beauties and pleasures of the sea shore with those of a well managed forest extending almost to the edge of the ocean.

There are evidences that the "Dunes" were naturally, originally fixed by forests. These forests were destroyed by vandals and all attempts failed to stop these menacing mountains of sand. In 1778 the talented engineer, de Villers, was sent to Arachon to form a military post. He saw at once the necessity of fixing the sand and was, according to Grandjean, the first to establish the fact that the way to fix the dunes was by means of plantations of pines. He met with troubles in his work and was finally sent back to the Island of San Domingo.

In 1784, Bremontier* began the work and, it is said, by using the result of de Villers labors, finally succeeded in fixing the moving sands .

The methods used in fixing the dunes were as follows :

A littoral dune was constructed straight along the shore from the mouth of the Gironde to Bayonne. This dune was the secret of the success in the fixation of these shifting sands. It is simply a bank of sand of certain dimensions with a certain slope suited to the conditions of the locality. This protecting or "littoral" dune is formed as follows : A double fence** is constructed of brush or of palisades driven into the sand. This stops the sand which comes from the ocean. Soon a ridge of sand forms equal to the height of the

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*Bremontier tells of a dune which advanced, in a violent tempest, at the rate of 2 feet in 3 hours.

**For diagrams see Plate 1 in the Appendix.

fence. A double fence is used as it gives breadth to the dune and stops sand which blows through the fence on the ocean side. As soon as the ridge of sand is formed as high as the fence, the old fence is pulled up, or a new one is built on top; and so on, until a dune of the desired height is formed artificially. The proper height of a protective dune is thirty-three feet. It should slope 25° (Gifford), 4° - 14° (Collier Cobb), towards the sea but may be 60° (Gifford), 30° (Collier Cobb), on the inland side. The dune must be at least three hundred (300) feet from high water mark. After the dune has reached its proper size, it is kept in shape by the sea marram" (Psamma or Ammophila arenaria) or "beach grass". This peculiar plant called the "gourbet" in France is exclusively used in fixing the sand on the "littoral" dune. It has long, much divided rhizomes and will grow well only when covered with fresh sand. The dune must always be kept in shape. If sand accumulates in any one spot in undue amounts, a draft is formed, which may end in a breach in the "littoral" dune. Guards are stationed along the dunes to watch it closely and here and there in this long, straight bank groups of men and women may be seen digging up "gourbet" in places where it is too thick, and planting in other places where it is needed. Constantly it is watched as many homes and lives are dependent on it.

After the formation of the 'littoral' dune comes the work of planting in its lee. The surface of the sand is covered with brush arranged like slates on a roof, with a shovel full of sand here and there to hold it down. Then the

seeds of maritime pine (P. maritima) are sown, with the seeds of other plants to shade the young pines. The pines usually come up well, and grow quickly although close to the littoral dune they are gnarled and stunted owing to the action of the salt winds. Thus, the sands are fixed and although the forests behind the littoral dunes do not yield a large cash income, they are of incalculable value to the people of Gascony and on the whole to France.

The fixation of the dunes rendered possible the work of M. Chambrelent, which was the reclamation of the Landes by drainage and planting. He first did some preliminary work with his own private funds and proved to an international jury that the work would be successful. The jury was so impressed with this work that they recommended using his methods on the whole region. In 1857 a law was passed whereby the state and communes paid for this work. The latter paid for the work by selling some of the land after it was improved.

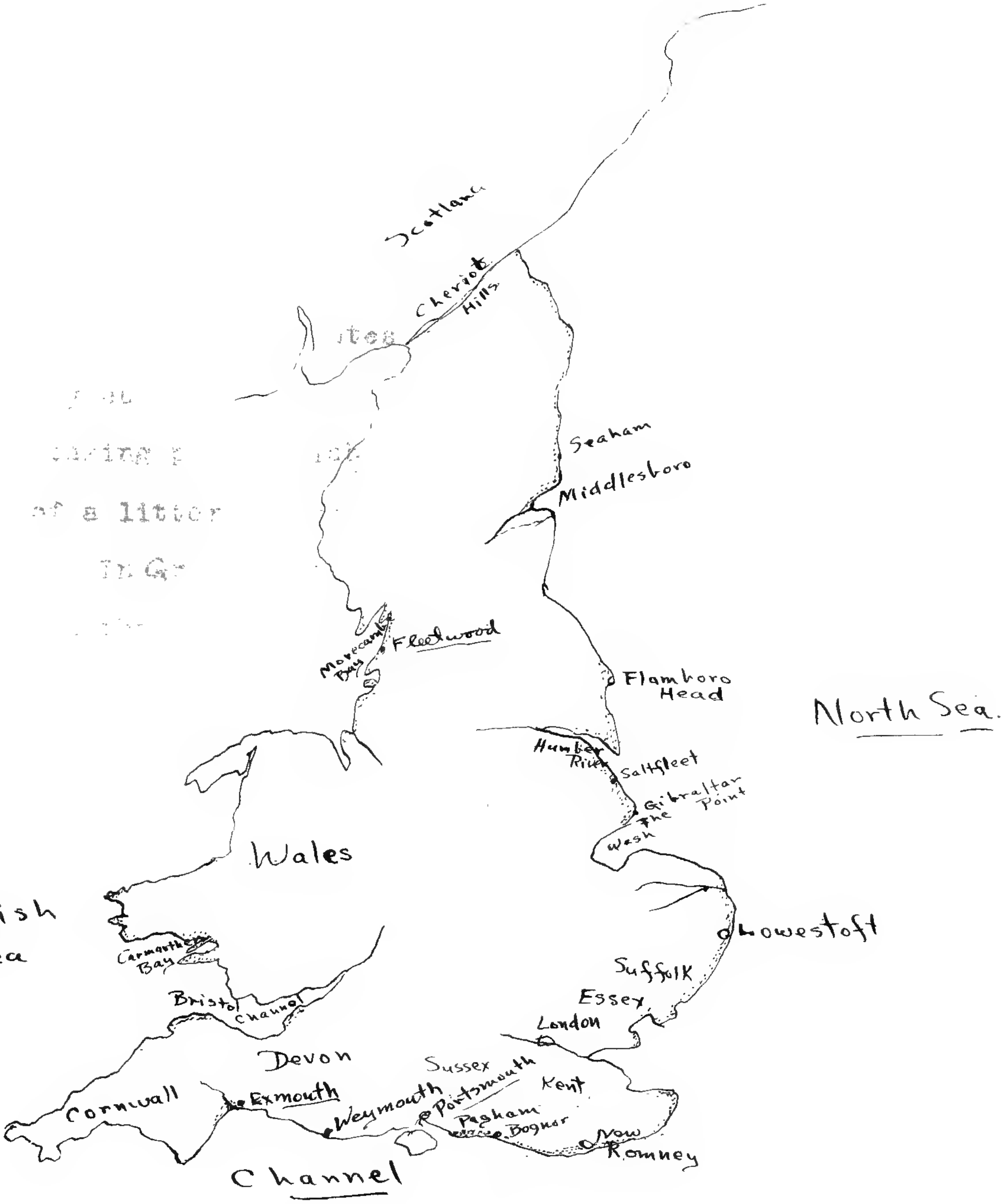
This region was about 100 meters above sea level, flat and sandy, and was underlain by a ferrugineous sandstone which formed an impervious hard-pan. In summer it was a burning sand waste and in winter an inundated swamp and between the two a period of pestilence. The country was characterized by its sterility and unsalubrity.

A complete system of drainage ditches was dug and plantations of Pinus maritima sown. This grew rapidly and the roots penetrated and broke up the hard pan without any great trouble. These trees relieved the sands of their

excess moisture and so moderated conditions as to change the climate to a most sanitary and healthy one. There is now an abundance of wood for household use and the turpentine industry supports many people.

The solution of this problem gives hopes for the reclaiming of many similar situations. This is especially true of the Atlantic Coast of the United States from Delaware to Georgia. The climatic conditions here being very similar to those of the "Landes".

Fig 5.



England.

precedes page 16.

## Great Britain*

As in most countries bordering the sea, Great Britain has a fringe of coast line which is sandy and contains many sand dune areas. While on the continent such dune lands have been largely reclaimed, little has been done in reclaiming these lands in Great Britain. Consequently there are many square miles of sand wastes and large belts of dunes only partially covered with vegetation. In other places erosion is now taking place which could be cheaply protected by formation of a littoral sand dune embankment.

In Great Britain there are many square miles of this dune area which might be rendered productive, and in such places, as the Culbin Sands, there are large sections of shifting dunes which are a menace to the country, destroying as they do in their inland march much fertile land and property. If systematic work was undertaken there is no reason why these sand deserts should not be reclaimed and even made productive enough to give a revenue.

In other parts of the coast where erosion is taking place the collection of inblown sand in the form of a protection dune might do much to prevent erosion at a slight cost. The Dutch have fully realized the value of sand dune embankments in their reclamation work.

In Great Britain the dunes do not generally attain

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*Case, G.O.** - 1914 Coast Sand Dunes, etc.

**The author states that no book on this most important subject has hitherto been published in Great Britain.

so great a height as they do in other countries. On the coast of Northumberland, the dunes which are often continuous for miles, are generally about 150 yards wide, and the maximum height is about 70 feet. Betweem Winterton and Waxham the height varies from 30 to 50 feet. In the Southport district where there are over 20 square miles of dunes, the height varies from 20 to 80 feet and in some places the belt of dunes is four miles wide.

In several places the mouths of rivers have been diverted several miles along the coast, At Christ Church, Hampshire, the sand drift is in an easterly direction, and an embankment has been formed across the estuary of the river Avon. Its continued growth has caused the river mouth to be moved along shore some distance in an easterly direction.

The estuary of the river Exe is partly closed by a sand embankment known as the "Warren". This sand spit was formed by the prevalent eastward drift of the sand. If these dunes were breached by the sea, the anchorage known as the "Warren Bight" would be destroyed and the Port of Exeter irreparably damaged. In fact this spit has been found so vital that the Great Western Railroad has constructed a sea wall,,groynes, and a dune embankment on it. Another similar locality is at Heacham, Norfolk.

Plantings have been made in many places along the shore. Longitudinal and cross-wind screens have been built to collect sand, and marran grass planted, at Carnarvon, at the southern entrance to Menai Straits, Pembrey Harbor Carmarthen, at St. Andrew's Harbor, Scotland and between Pagham and Bognor on the Sussex Coast. At St. Andrew's Pinus

maritima was planted.

One great problem on this coast was to prevent erosion. This was done by the construction of groynes. The object of the groynes was to prevent erosion and to build up the fore shore by causing the currents to deposit the fine material held in suspension.

In designing a system of groyning care was taken not to divert the currents running parallel to the shore either by making the groynes too high or too low or other than at right angles to the main current. If the groynes are more than three feet high irregular accumulations, if any, takes place. The distance apart is best that of the distance between high and low water levels. The direction is usually best when at right angles to the shore and extending from high water mark as far seaward as possible. Cement groynes have been found the best as they are easy to make and permanent.

In some places where the storm erosion was great a facing was constructed. This was usually of cement and extended from the high water mark to the level where plant life grows. In some countries, especially Holland this facing extends over a mile along the shore where the storm erosion is the greatest. It is only during storms that the waves beat on this facing.

Back of this the usual methods of forming a littoral dune are used. This area is planted with grasses and then with forest growth. The methods as used on the "Landes" are followed except that the following growth is used :

## Plantings on the Littoral Dune (Sea face)

As a rule it is impossible to attempt to plant trees on the littoral dune owing to the salt spray of the waves and the strong sea winds. The sand grasses most suitable for use on the littoral dunes are: Marram grass (Ammophila arenaria), Baltic Marram grass (Ammophila baltica), Sea Lyme grass
B
(Elymus arenaricus), sand sedge (Carex arenaria), sea couch grass (Triticum junceum), etc.

## Plantings on the Littoral Dune (Land face)

Among the shrubs suitable for growing on the land side of the littoral dune are: Sand willow (Salix repens), sea buckthorn (Hippophaë rhamnoides), tea tree (Lycium barbarum), tamarisk (Tamarix anglica).

The trees most used for planting on the dunes are : the Black austrian pine (Pinus austriaca), Scotch pine (Pinus sylvestris), the Corsican pine, Maritime pine (P. maritima), Scotch fir, and the Sand willow (Salix repens).

In the most exposed parts the black Austrian pines have done the best and should be the only trees planted on the sea side adjoining the protection dune. In less exposed places the Corsican pines have been found the most useful kind of plant, this variety having the advantage that rabbits will not destroy them. The Scotch pines were found to be successful but the sea pines (P. maritima) were found to bush and so are now discarded. The cost of planting these trees in the lee of the littoral dune was found to run to about 7 pounds 10 shillings per acre in favorable situations.

## Dune Laws and Regulations

In the reign of Queen Elizabeth an act was passed to prohibit the destruction and to encourage the cultivation of vegetation on sand dunes. Another act was passed in 1741 to prevent the cutting of marram grass on the sand hills of Scotland and the northwest coast of England. A penalty of 20s was imposed on those who, without proper authority, but the same on the hills or banks of the northwest coast of England and later this act was extended to Cumberland.

However, these laws applied only to limited localities and did not protect the whole coastline as they should have done. Even at the present time there are only local laws to prevent the destruction of the grasses on the littoral dune. These are effectual in but few places and where they have been enforced have resulted in the dunes being covered with vegetation. In order to afforest the dunes laws should be passed prohibiting grazing on the littoral dunes and the land in their lee. Then with the formation of a Dune Department, with proper authority, as in France, the dunes would cease in time to be a serious problem.

## Reclamation of Sand Dunes on the Atlantic Coast of the United States.

According to Hitchcock* the chief areas of shifting dunes to be found along the Atlantic Coast are on Cape Cod in the vicinity of Provincetown, southern New Jersey, near Avalon and Stone Harbor, Cape Henry, Virginia, Cape Henlopen, near Lewes,, Delaware, and less extensive though quite troublesome dunes at Currituck, North Carolina, Isle of Palms near Charlestown, South Carolina and Tybee Island near Savannah, Georgia.

J. Wayland Vaughan** Director of the U.S. Geol. Survey in a personal letter gives the following information in regard to dune formations on the Atlantic Coast: "There is a good development of actually moving dunes, at least in places, along the coast of South Carolina, in Horry County, and a fairly good development of dunes, in the vicinity of Charlestown, South Carolina, on Sullivan Island. The occurrence of dunes on the Georgia Coast is mentioned in "Geologic Survey of Georgia", Bul. #26, p. 37 and in U.S. Geol. Survey Water Supply paper #341, pp. 36 and 37. There are dunes on the east coast of Florida, in the vicinity of Hobe Sound. An account of the latter is found in U.S.Geol. Survey Water Supply paper #319. I do not know of any published account

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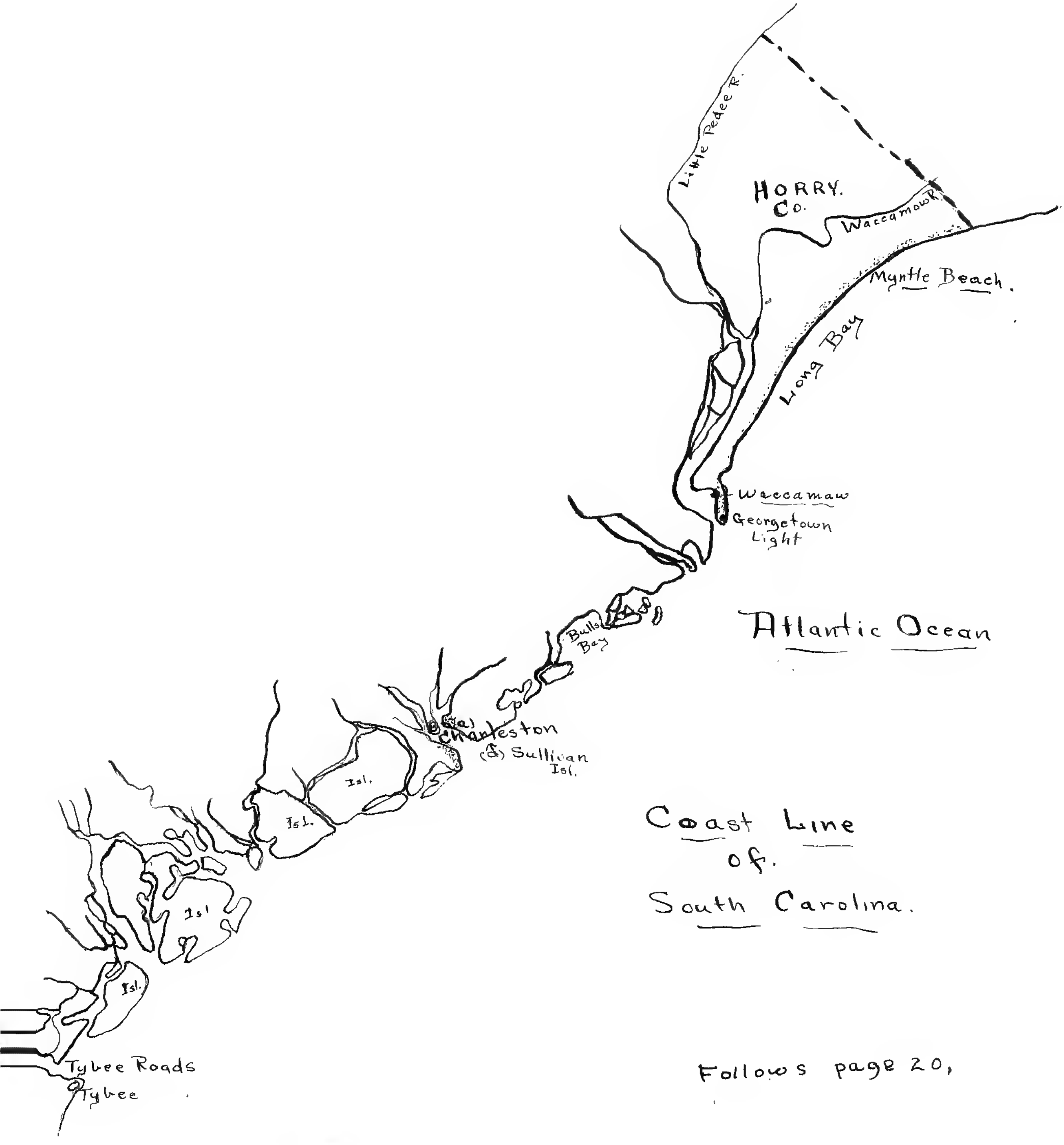
*"Controlling Sand Dunes in the U.S. and Europe" by A. S. Hitchcock, U.S.D.A., Nat. Geog. Mag. 1904, p. 43.

**According to Prof. Harris of Cornell University Mr. Vaughn is the authority on Atlantic Coastal conditions.

Fig. 6.



Coast Line of South Carolina.

Follows page 20,

of the dunes along the coast of South Carolina. Of course, you know of the superb development of sand dunes between Cape Henry and Virginia Beach, just east of Norfolk, Va."

The section where the most important work has been done is on Cape Cod near Provincetown. This section is discussed fully as being the basis for similar operations on other sections along the coast.

## Sand Dunes in Maine

There is little information about sand dunes in Maine. In only one locality are they of any importance and the data on this locality are very meager.

*Stone gives the account as presented in substance below :-

"Drifting sands of the 'ordinary' type are very common in Maine, especially in the western half of the state. These sands are partly of marine, partly of fresh water deposition. *All the large rivers of Maine, except the Penobscot, covered large areas with sand near where they emptied into the sea during the Champlain epoch, the sea at that time being, as is well known, somewhat more than two hundred feet above its present level. Of these river valleys, that of the Androscoggin is preeminent for its dunes. One can travel in a carriage along this river from Brunswick to the New Hampshire line at Gilead and view dunes almost continuously for an hour at a time. In Wayne,

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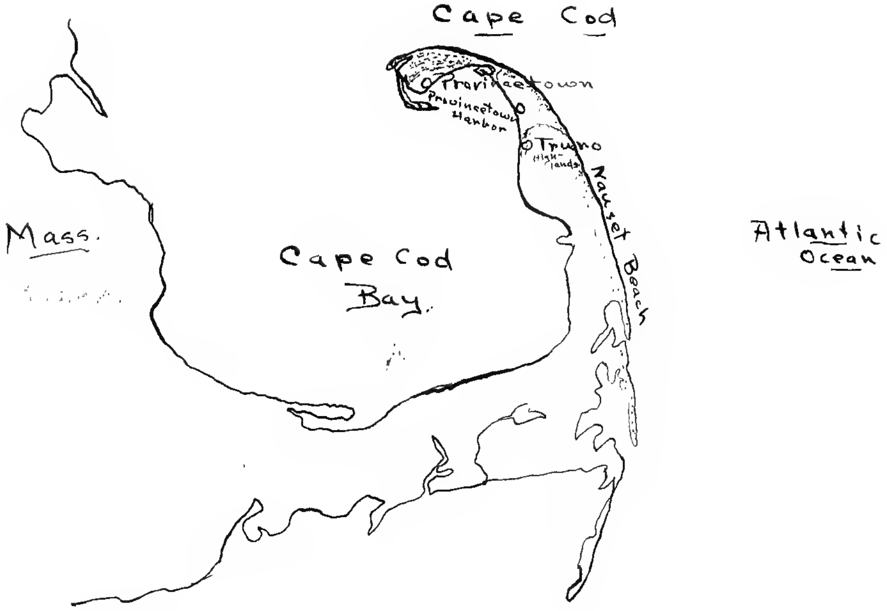
* "Wind Action in Maine" by Geo. H. Stone, Silliman's Journal, 1889, p. 133.

Fig 7.



Dune Area of Cape Cod.

See Plate II for details.

Follows page 21.

within the last forty years, the sand has drifted eastward one-half to one mile and up the slope of a hill 250 feet high and is now descending the slope. In places some of the dunes must have traveled two miles or more from their original river valley. Often a hillside is covered with pine where one would most naturally find deciduous trees. Investigations have shown that dunes have passed over this hill leaving a sand covering over the till on which the pines have grown."

Although there are little or no other data on this subject the general conditions inferred, i.e., slow dune movement, and rapid pine growth, seem to indicate that the balance of natural conditions in Maine are unfavorable to traveling dunes.

## Sand Dune Area of Massachusetts.

Outside of the Cape Cod region there are no dune areas of importance in Massachusetts. It is this area which has claimed the attention of the Commonwealth in regard to dune reclamation for over a century.

### Reclamation of Cape Cod Sand Dunes*

Cape Cod Harbor** has been a most important harbor especially for fishing and for a convenient anchorage for many vessels during storms. It has also been used as a naval base.

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*"Reclamation of Cape Cod Sand Dunes" by J.M. Westgate, Asst. in sand binding work.

**See Plates in Appendix.

At one time this neck was covered with forests but with their removal the sands formed dunes which are moved by every strong wind. These sands in moving have covered over what little timber remained, filled in parts of the harbor and have threatened many little villages. To overcome these dunes has been a problem which the local, state and federal government have worked at for years and we have a record of beach grass plantations established over two hundred years ago.

Mode of Deposition of Cape Sands,- The arm of the Cape extending around Cape Cod Bay consists of glacial deposits, with the exception of about ten square miles which is composed entirely of **post** glacial sand which has subsequently been washed around the head of the Cape from the south, enclosing the harbor within a sickle shaped sand bank.

The addition of sand to the extremity of the Cape apparently takes place in the form of successive bars, which are built up off the north shore and added to the Cape by deposition in the neck of the channels lying to the east and south forming successive "race runs" (Plate 2) which are being gradually filled in by tide and wind deposits. The sand cast up by the waves on one of these new beaches is dried and blown inland, forming a beach ridge or fore dune and eventually a dune range, which,protected by succeeding deposits ultimately becomes covered by the forest and associated vegetation.

The above facts are supported by the construction

of the neck and character of the dunes.

With this method of deposition it follows that the necessity for sand fixation will never cease unless the sand supply from the shore drift becomes exhausted. However, the process of sand accumulation is so comparatively slow as to be of little importance when compared with the more serious conditions incident to the extensive areas of sand dunes only partially reclaimed.

Development of the Dune Range.- It is probable that each of the seven dune ridges which constitute the greater portion of the extremity of the Cape was developed in a similar manner, from the successive beach ridges and ensuing fore dunes, by the accumulation of the sands blown up from the beaches. As will be noticed later the vegetation plays an important part in this dune formation.

As soon as the sand deposited by the waves is blown up to a point beyond the action of the tides the beach grass, associated with the typical strand vegetation, spreads rapidly over the surface and retards the movement of the resulting beach ridge. As the sand accumulations continue, the ridge becomes a fore dune. The beach grass pushes its way up through the accumulating sand by the formation of new root stocks, thus keeping the ever increasing area of sand comparatively well covered, since the gradual addition of sand constitutes one of the essential conditions for the ideal growth of the grass. The fore dune continues to rise and other species of plants come in but ultimately a height is reached where the unbroken winds on this exposed land are

sufficient to prevent the vegetation from holding the sand. At this stage the long fore dune becomes a dune range and begins to move inland, covering the preexistent vegetation in its path. The movement continues until the dune ridge is sufficiently removed from the unbroken force of the ocean winds to permit the formation of a dense vegetative growth sufficiently dense to prevent its movement. The forested condition ultimately dominates.

The beach ridge may be formed from sand accumulations from the waves or it may develop from a sand bar which becomes attached to the mainland.

Of the seven dune ranges constituting the body of the extremity of the Cape, only the inner four are at present forested. These are badly distorted, but were probably formed as has just been indicated, as the changes through wind and human action have not entirely destroyed the traces of their formation. These ranges are covered with a growth of pine and oak, with an occasional beech in favored locations. The outer three ranges are covered with scattered growths of beach grass. The depressions between the ranges are characterized by wild or partially reclaimed cranberry bogs and the associated vegetation. It is probable that all of these ranges except the outer one, were at one time forested, and have been brought to their present unstable condition in historic times.

Two of these causes*, fires and grazing have been

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*"Forest Legislation in America prior to March 4, 1789" by J.P Kinney, Bul. 370, Cornell Ag. Exp. Sta. 1916, p. 397. In this bulletin the author shows the historical development of legislation in the control of these dunes. The laws were directed towards overcoming the evil effects caused by fires and by grazing.

practically wiped out through protective legislation.

Artificial Reclamation of the Cape Sands.- The devastated sand areas of the extremity of the Cape are known as "Province lands" and are owned by the state. It is here that the greatest amount of work has been done to overcome the moving sand dunes. With the fixation of the dunes in this area the remaining land should in time reforest itself provided grazing and fires are prevented from doing damage.

Early plantings were begun by the State in 1826 and consisted of an extensive and systematic attempt to reclaim land by the use of beach grass. The operations covered twenty-eight years and in cost aggregated $36,350. The amount of good and actual success of this work can not be determined. The greatest successes were in building up a break caused by the sea at East Harbor, and the growing of beach grass on the bulksheads. The latter caused the sand to accumulate and protect the harbor from the sea. The fact that two-thirds of the non-forested areas were covered with beach grass at the end of the last century indicates that the plantings may have had quite a lasting effect.

The chief criticism of these operations was that the plantings were too much confined to high places where they were blown off and that the beach grass was not supplemented by plantations of shrubs and trees*.

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*See Hollick A. "Geol. & Bot. Notes" Cape Cod and Chipp Island. Bul. N.Y. Bot. Garden. 2:381 - 407.

## Recent Work by the State

**Preliminary Operations.**- It was not until 1892 that real organized work was done in reclaming the dunes. At this time the state relinquished its rights to the land within and immediately adjoining the city of Provincetown, leaving but 3,290 acres under state control of which approximately 2,000 were non-forested.

In this work there was expended during 10 years ending January 1, 1904, the sum of $31,929 of which $10,950 was spent in planting beach grass, and $6,011 in the introduction of woody growth.

At first the three great dunes on the north shore of the Cape were bare and were marching on the city and harbor at the rate of fifteen feet a year. These were planted with shrubs and tree seedlings. The result was that heavy winter gales uprooted some and killed the rest by the blasts of sand.

The next season beach grass was planted to supplement the new woody growth. This planting was done both in fall and in spring, it being found out that there is comparatively no difference in results from using either planting season.

**Selecting and Transplanting the Sets***- The plants selected for transplanting are vigorous and well rooted and this usually means two-year old stock.

When setting out the grass it is customary for two

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*See plates in Appendix.

men to work together. The one with a shovel inserts it deeply into the sand as far as the foot can force it. A backward pull of the handle loosens the sand at the bottom of the hole, while a forward thrust produces an opening behind the shovel sufficient to accommodate the plant, which is placed in the hold by the second man. The shovel is withdrawn and the sand trampled about the plant. The shovel is next inserted about a distance of 20" from the first, and all is ready for the next set. By this method of planting two men can set 600 plants per hour.

Cost of Planting.- The cost of planting depends upon the thickness at which the grass must be set. On more exposed areas requiring thick setting five men procuring sets, two teamsters, 8 planters working 9 hours per day are able to cover an acre in two days. With wages at $2.00 per day the cost is about $65 per acre. This is with abundant planting material not more than a mile away. On the more thinly planted areas the cost for 279 acres, covered with grass was $50 per acre.

The plantings of the first two years were made in rows ranging from 12-18 inches apart with the plants 12" or less in the row. This, however, has been found less satisfactory than irregular planting as the wind sweeps the sand down the row. At present the plants are set about 20" apart but this is not necessary except on exposed areas. The thinner spacing gives more root area for the sets, and this helps maintain the vigor of the transplants. Also the extra cost of thick planting is not justified. It has been

the custom to protect the plantings with lateral brush hedges. The larger branches are set vertically in the ground at intervals of 2 - 3 feet and the interstices filled with smaller brush. These hedges protect the plants from wind erosion and catch large quantities of sand.

In some areas the small and isolated elevations have been covered at considerable expense with grass. This has been thought to be an unnecessary procedure as the wind levels these elevations, furnishing a gradual accumulation of sand over plantings on lower levels which increases the vigor of these plantations.

Brush laying,- In laying brush the best method has been found to be one of uniformly laying brush over the plantings. The brush holds down the sand and while it makes a condition not best for the growing of beach grass, it survives and by the time the brush decays has prepared the way for succeeding vegetation. The laying of brush has been carried on extensively on roadways through the dunes. The total area thus covered has been about 15 acres at the cost of $25.00 per acre. The addition of leaves, humus, etc. is beneficial although not a necessity.

Efficiency of Beach Grass for Sand Binding,- Although many countries have tried other grasses, the beach grass (Ammophila arenaria) has no rival in this work. The long, tough, flexible leaves of the beach grass enable it to endure the action of the wind with little detriment. A bunch of dead grass will stand two seasons of wind action

without being destroyed. The root stocks penetrate the sand, tending to hold it together and the leaves tend to accumulate sand.

Beach grass usually requires a gradual accumulation of sand over its crown to become effective. In fact a healthy growth of beach grass can thrive where the sand is not more than a foot a year. In places where the sand accumulation is deficient the growth of beach grass deteriorates soon.

The necessity of sand accumulation lies in the fact that it induces the development of new root stocks by the old plant and thus occupies an unused portion of the sand which presents such a dearth of food salts that these are soon depleted and the deterioration noted must soon ensue unless new acres of sand are made tributary. Furthermore, there is no power of downward growth of root stocks, and the root system is very limited, often but two nodes.

Another reason for the deterioration noted above may be the fact that a single set of the grass is not of indefinite existence, and unless induced to increase vegetatively, loses its vigor.

At Poplar Branch, North Carolina, the beach grass has increased in vigor since the plantations were established. This is apparently due to the fact that the plantings were made sufficiently apart ( 4 feet) to allow most of the sand to drift through the plantation and thus enable each set to receive a small amount of sand. With this thinner planting we have a great deal lower cost - as low as $8.00 per acre.

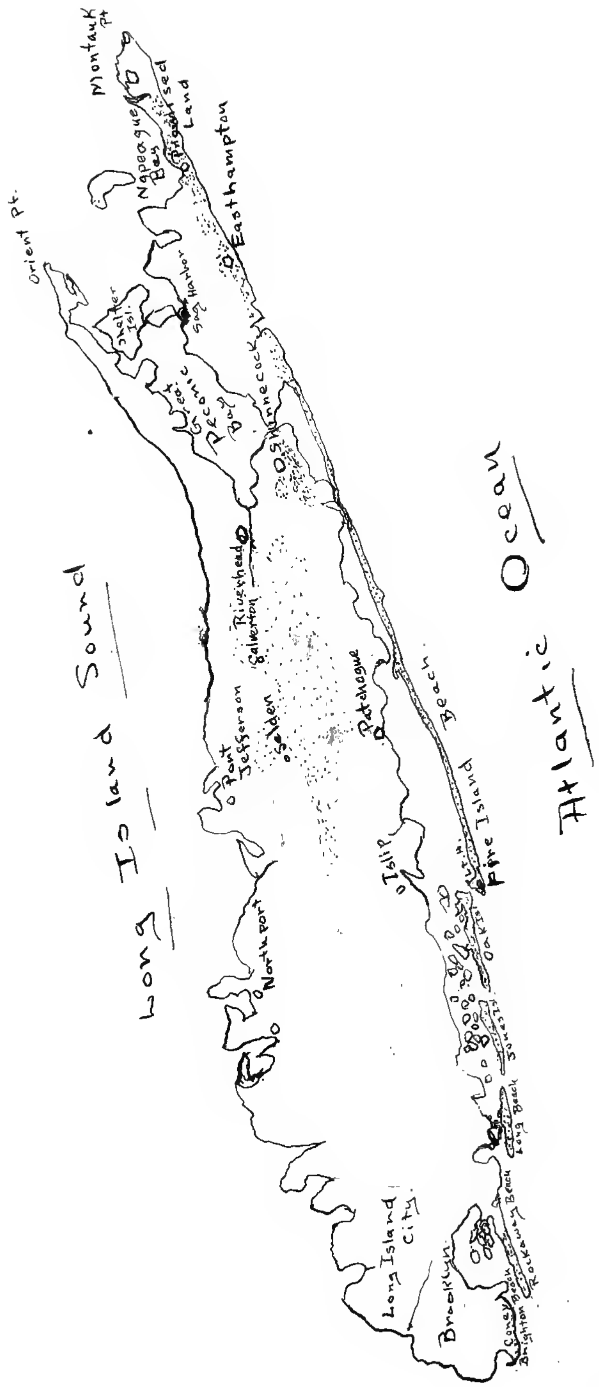
Necessity of Ultimate Reforestation.- The marked deterioration of beach grass shows the need for introducing woody growth over the dune areas. The various native or imported woods should be set out among the grass as soon as it is planted, as the first year's protection by the grass is the best and not too long to give the shrub or tree a chance to get a good rootage.

It seems it is necessary to start such a shrub or bush as the bayberry (Myrica carolinensis). This is not injured by unfavorable condition and seedlings of pine and oaks may be safely introduced among the bushes.

The successful species for such work are comparatively few in number. Of the pines, pitch pine (Pinus rigida), Austrian pine (Pinus laricio) and Scotch pine (Pinus sylvestris), are successful. The pitch pine is used most extensively as it grows in adjacent forests and the seeds are the easiest to obtain. The black locust (Robinia pseudo-acacia) and black alder (Alnus glutinosa) have been found most satisfactory and will be introduced over large areas. The bayberry has formed the bulk of the pioneer plantings of woody growth, and used in connection with the beach grass appears to be the only necessary forerunner of the pines.

This work has been highly successful and has resulted in the building up of the whole area. Cranberry bogs have been improved and strawberry growing has developed. However, the land never has been of agricultural value and probably never will.

Fig. 8.



Long Island.
(Sketch)
Showing Dune Areas.

Follows page 31.

The chief value of the reclamation of these dunes is in protecting the harbor.

For other purposes the work could well be continued for a marine park and as a summer resort. Especially since the work of protecting the harbor will give ideal resort conditions this offers great possibilities. The successful development of the Golden Gate Park of San Francisco has demonstrated the possibilities of such sand tracts when reclaimed.

## Long Island* **

### Wind Deposits, Character and General Distribution

Although not covering extensive areas or reaching heights so great as those of some other localities along the Atlantic Coast, the dunes of Long Island are at many points a conspicuous local feature.

The dunes in process of formation at the present time, with few exceptions, are limited to the immediate vicinity of the beaches. At Easthampton, however, dune sands occur for a distance of 1¼ miles from the shore, and there is also a considerable area in the interior of the Island, between Patchogue and Port Jefferson, where wind action has been active in the past and is observed locally even at the present time.

*The Geology of Long Island, N.Y., by Myron L. Fuller, U.S.G.S. Prof. paper # 82.

**Pop. Sci. Monthly, Vol VIII, 1876, p, 357.

The dune sands consist almost entirely of fine quartz grains, well rounded and often mixed with heavier magnetite granules. The dunes generally rest on a black loamy soil zone, if they are of recent formation, or on a brownish, oxidized zone from which the organic matter has been leached, if they are among the older dunes.

## Dunes at Napeague Beach

Napeague Beach and vicinity constitute the most conspicuous dune area on the Island. Five miles long and two miles wide it comprises little but irregular sand heaps from 10 to 30 feet or more in height, between which are many small marshes fed by fresh waters caught by the dunes. Leading westward from Napeague Harbor is a large, fresh water marsh, half a mile wide, lying between the dunes of Napeague Beach on the South and the Promised Land on the North. The dunes reach their greatest development just east of the harbor, where they have an elevation of 100 feet. It is possible. however, that a part of this height is due to the underlying strata. The dunes of Napeague Beach have derived their materials from the shore wash from the east; those east of Napeague Harbor seem to have been mainly supplied from the same source with little additions from the north side, their accumulation taking place mainly under the action of Southwest winds. The dunes of Promised Land are from a similar source. The big marsh between the dune area does not seem to have been crossed and it is possible that very little of the material has come from the south.

## Dunes of Easthampton

In the main the dunes of the south shore are confined to a narrow fringe along the beach, but at Easthampton the drifting sands have gone in one or two cases as far as $1\frac{1}{4}$ miles inland or as far as the railroad. The sandy character of the roads probably has extended considerably north of the railroad and westward to and beyond Georgica Pond, although this is not conspicuously shown by the topography. East and west of the town the dune structure is very noticeable. This area, however, is now being covered with summer residences, and the dunes are largely under control.

## Dunes of the Great South Beaches

The barren beaches which extend along the south coast for nearly 90 miles are lined throughout their length by more or less strongly developed dunes, generally 15 - 20 feet in height. Along the inside of the outer beach, the dunes form a rather uniform and continuous though somewhat notched ridge some 20 feet in height and extending for miles along the shore. On the inside of this barrier there is also very commonly a second ridge, which, however, is lower and less continuous than the outer one. Between the two there is generally an area of lower and flatter dunes among which are scattered knobs; many rise to a height of 20 - 30 feet. Between these ridges or among the lower intermediate dunes many fresh water marshed are found. Some of these merge with the salt marshes which line the inside of the barrier. The finest dune development is found on Fire

Island and Rockaway Beaches, although the latter, as well as the dunes on Coney Island, have been much modified by human agency.

## Dunes at Shinnecock Hills

The Shinnecock Hills are composed of the Manhasset formation in which, in this area, sand predominates. In the past this sand has often been taken up by the winds to form dunes, and to this action a part of the irregular surface topography of the hills is due. A hundred years ago much of the surface was composed of drifting sands, but now the sands are mostly under control although a little drifting still takes place.

## Dunes of the North Coast

Practically every bluff section along Long Island Sound shows a layer of dune sand at the top, and some small valleys are filled with it, as near the Woodhull Landing, northeast of Miller Place. Usually this sand is only 2 - 5 feet deep, but some of the dunes are conspicuous hills from 50 - 100 feet high. They all rest on an old soil zone marking the horizon of the original surface.

On this side of the Island the dunes are best developed between Baiting Hollow and Northville, north of Riverhead, where they form a high and nearly continuous ridge more than 8 miles long. The great mass of the ridge in this vicinity is composed of sand resting on the Manhasset terrace. Many parts of the dune ridge are very old, so that the humus of the underlying soil zones has been entirely leached out.

Much of its surface is covered with forest. Some arable land has been covered and one farm near Baiting Hollow lost 130 acres between 1846 and 1886. This dune, however, is now mostly covered with small tree growth.

Another important dune area is near Southhold, where the shore back of the beach is lined with dunes of moderate size. Though more or less covered with trees the sand is still blowing. There are several fresh water marshes among the dunes and a pond is enclosed between the drifting sand and the bluffs.

Dunes in the Interior of the Island.

In the western half of Long Island there is little indication of dune formation and these do not present any problem in regard to control.

From Coram eastward dune sands are common both on the plains and moraines. The part of the moraine south of Riverhead and southwest, south and southeast of Sag Harbor, is especially characterized by such sands. In most cases they were formed before the region was forested.

Very large areas of similar sandy surfaces lie north and northwest of Patchogue and between Patchogue and the morainal ridge.

The moraine and plains south of it are covered with forest or brush and few evidences of wind action are to be seen. At the north base of the ridge near Selden, however, and at points eastward to Coram, westward to and beyond New Village and northward one-half way towards Terryville, not only does the surface consist of fine sand but in 1903

many spots free from trees and almost free from vegetation showed a subdued dune topography. It is believed that this region was once forested and protected from winds, as the dunes would be much more strongly developed. The opportunity for present wind action to arise is thought to have been given by the destruction of the forests and the vegetable mold of the soil by fires that have repeatedly passed over the region. What the ultimate results will be can not be foretold for the conditions appear to be nicely balanced. If fires can be kept out, vegetation will soon cover the burns and restore the forests to its supposed former, unbroken state.

## Control Measures on Long Island

The dune formation near Easthampton is well under control. This is due to the vicinity being a popular summer resort and the building up of these dunes and planting has eliminated the dunes from being a problem for reforestation.

This is also true of Napeague Beach although there are but few estates in this vicinity. It is, however, probable that the near future will see a big shipping terminal at Fort Pond Bay with the building of storage and other houses on this dune area.

The dunes of the Great South Beaches is hardly a problem for reforestation. Coney Island is well built up and the dunes have been covered with a great variety of plants.

The dunes of Fire Island Beach have been much modified by human agency. However, the land is so cheap and the damage from moving sands so little that it would not pay

to reforest this land.

The dunes of the Shinnecock Hills are almost a thing of the past. I have been over all of this section and have seen nothing but huge golf links, millionaire residences and homes. What were once sand dunes are not covered with heather and red cedar. This section is being rapidly planted by private enterprise.

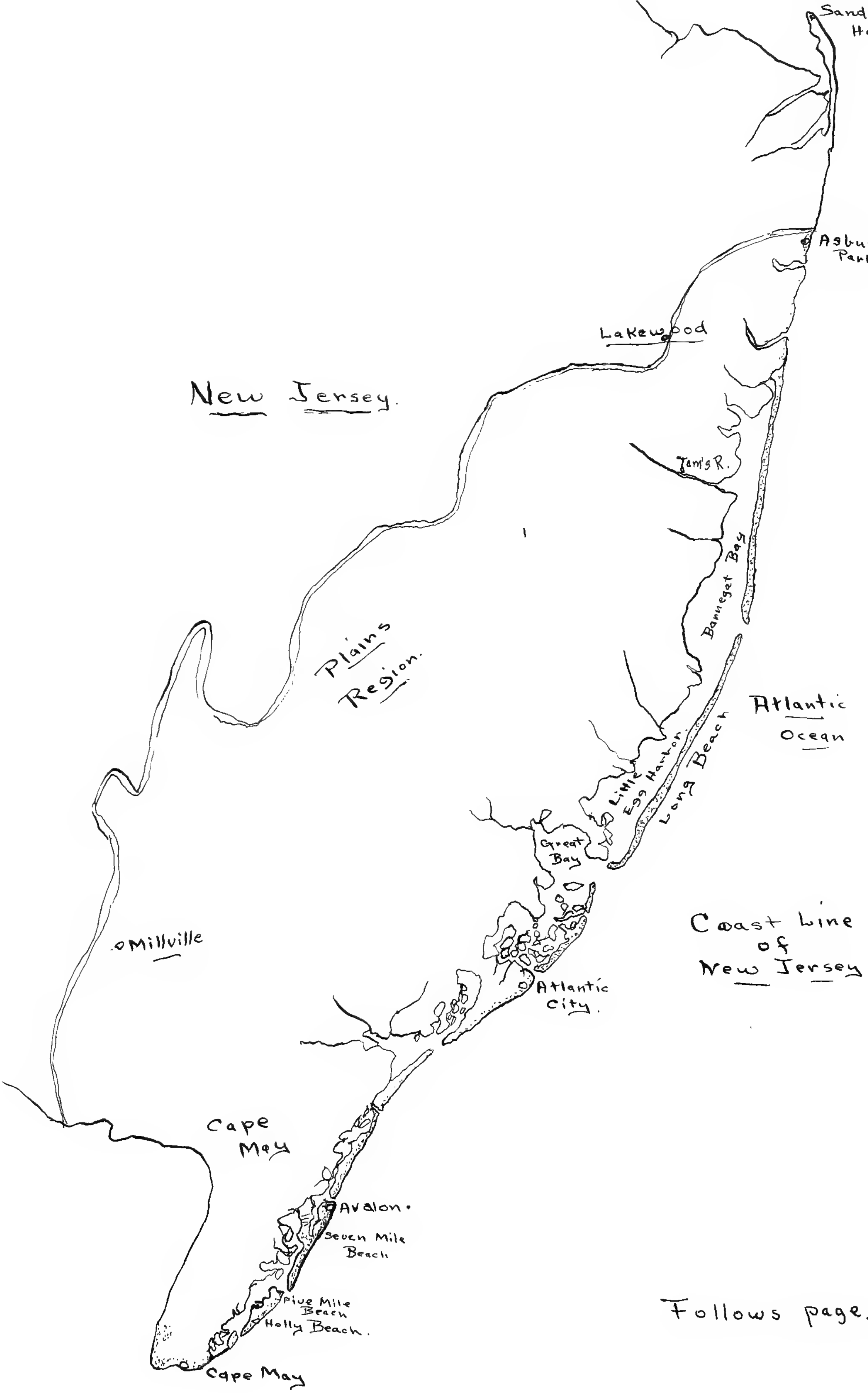
The dunes of the north coast are limited and are rapidly being covered with forest growth. This is largely due to the prevention of forest fires through cooperation of the counties and Long Island Railroads.

The dunes in the interior of the Island present the same problem as to control. Prevent the forest fires and the sandy surface is quickly covered with scrub oak, red cedar and especially pitch pine, besides a variegated vegetable growth.

In all, the dunes on Long Island are of minor importance and are being overcome by private enterprise and settlement. The prevention of forest fires for a number of years will result in this area being covered with tree growth.

For actual work in reforestation the use of pitch pine would be advisable as it is naturally adapted to the climatic conditions and can withstand the frequent ground fires as no other tree can.

Fig 9.



Coast Line of New Jersey

Follows page. 38.

## Coastal Plain and Dune Region of New Jersey*

The wooded zone of southern New Jersey, which is known as "The Pines", has some sharp contrasts between its coarse, sandy soils, covered by the pitch pine, almost exclusively, its white cedar swamps, and its mixed swamp lands. The size of the holdings is large, running to tens of thousands of acres. The averages of fires and severe cuttings have left scarcely any large timber. The frequency of forest fires have left large areas of dry, sandy soil covered with little more than scrub oak and pitch pine. The care of the forest on the whole is practically of no value in promoting better growth.

However if this area especially near the coast should be denuded of forest cover by successive fires this sandy district will become a forbidding waste of shifting sand, blown hither and thither by varying winds. Something of this kind may already be seen in many old clearings, notably near Manumuskin creek in Cumberland County, where the sand is piled up in great shifting dunes. The mild winter climate of the region, which deserves its increasing popularity, will undoubtedly be most unfavorably affected, for it is due in no small measure to the shelter afforded by the pines against the cold west and northwest winds.

In a survey of the northern coniferous area the common pitch pine (P. rigida) and the hemlock pine (P. virginiana) was found to be common especially on upland sites.

*Forestal and Silvicultural Prospects of the Coastal Plains of New Jersey John Gifford, 1899.

Going farther south and east towards Bridgeton and Millville the pitch pine was found to be more numerous. Going toward the western limit of the coniferous area, near Maurice River, P. virginiana supplants P. rigida to a large extent. This shows the natural possibilities of the species for the site.

The forest fires on the Coastal Plain of New Jersey have a most serious effect on forest reproduction. It is only the persistent sprouting of the burned pitch pines that allows of hope for the future in regard to pine growth in New Jersey. The soil becomes so dry and bare that seed reproduction is very difficult.

The original timber of the greater part of Southeastern New Jersey was pine which occurred in heavy growth. The poorer soils were probably occupied by pitch pine and the better soils by shortleaf pine. Besides forest fires the pines have to overcome a deficiency of moisture and a hard subsoil which the roots find difficulty in penetrating.

Along the seashore the only predominant sand dune area is at Holly Beach and Anglesea although near Asbury Park and its environments buried forests in recent sea beach deposits have been found. From Lakewood through the heart of the coniferous zone the chief trees are : P. rigida, P. echinata, Q. alba, and Q. velutina. Sometimes other mixtures are found to prevail in special localities.

Pinus rigida is exceedingly abundant in the coniferous zone where it often forms the bulk of arboreal vegetation over large areas. It is the characteristic pine of the coniferous zone. P. virginiana is found in scattered groups

throughout the whole coniferous zone. P. echinata is not very abundant in this zone but with the preceding species may be considered characteristic especially in the marl belt.

The Coastal Plain of New Jersey is the northern extremity of the Atlantic Coastal Plain. Its area is about 2,500 square miles. The climate is greatly similar to that of western Europe and it enjoys the rain and shine of Italy. The zone in which it falls is known as the Carolinian and is largely forestal.

Throughout the entire mainland of this region very light sandy soils prevail although clays, gravels, and loams are often found. In spite of a hard subsoil, drainage is good. A part of this area is noted for its unsalubrity and the pineries of the Jersey plains are proverbial for their poor soil, with little vegetable growth due to repeated fires. Prevent these fires and the region will become covered with tree growth especially mixed woods with oaks.

East of this plain along the shore we have many salt marshes. Protecting these are long barriers of beaches or sea islands. These beaches which are separated from each other by inlets through which the tide sweeps swiftly are often famous for their summer resort colonies.

When the tide is out the sand dries and is easily blown by the wind into sand hills. Any small object which stops the wind may start a dune. However, changes in the direction of the wind often blows these dunes into the sea.

A great deal of the land on these islands is owned by private parties and in many places extremely valuable. But here and there are wild, shifting dunes. At Avalon

there is on Seven mile beach a huge dune caused by a forest which it is slowly but surely engulfing. This dune begins just at high water mark and extends inland rising gradually inland until its top is just even with the tops of the trees.

This dune like others is not dispersed as the forest protects it from the west winds. Open up large sections of the forest and this dune if not disappearing would at least remain stationary and become fixed by the rapidly growing vegetation.

These Jersey dunes are not dangerous although threatening in some places. In fact they have a charm of their own, but which are being rapidly destroyed as the dunes become the sites of fashionable summer resorts.

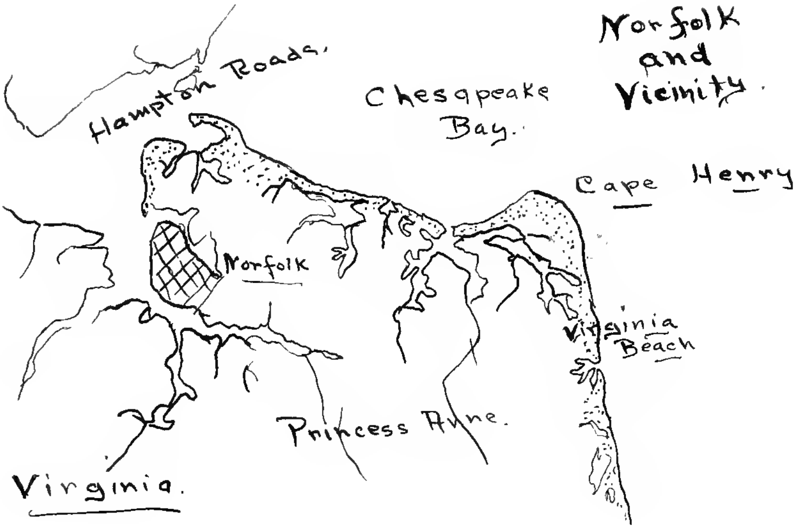
In south Jersey the smooth-bark pine should, because of its greater value and desirability, be encouraged. Where this does not grow best, pitch pine should be grown, etc.

## Cape Charles Peninsula

South of New Jersey on the peninsula* between the Delaware and Chesapeake Bays, the forest **litter** of the pineries is an industry in itself. This demand for the pine needles or "pine chat" is so commercially valuable that the forest has been taken care of. This has impressed upon the natives the value of the forest and has eliminated forest fires.

*John Gifford, "Forestal and Silvicultural Prospects of the Coastal Plain of New Jersey".

Fig. 10.



Dunes of
Norfolk and
Virginia Beach.

Follows page 42.

The soil being composed of a light sand is dune like in character especially along the shore to which the pines grow close. However, it is only in a few places that the shifting sands have killed any of the pines.

The natives recognize the value of the forest in giving them a source of income besides acting as windbreaks for their truck patches, which seem to alternate with their pineries. The pine areas due to economic conditions are well kept and thrifty and need no government supervision.

## Sand Dunes of Lewes, Delaware *

It may be stated in advance that, while the conspicuous change in the surface has been most marked towards Cape Henlopen, the marshes between the Breakwater and the mouth of Lewes Creek, has been slowly rising; that whereas these mouths were at one time regularly flooded, this rarely occurs now. South of the Breakwater, about one-fourth of a mile inland, one encounters a mass of pure shore sand, probably in its greatest depth, one hundred feet deep, becoming on the north, south and west, less and less deep until one reaches nearly sea level. On the top of this ridge the limbs of dead and buried forest trees protrude. On the northern slope they become less and less abundant until one reaches marsh level. North of this, towards the water's edge a second growth of trees is seen appearing. On the

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*By Prof. J. T. Rothrock, Proc. Acad. Nat. Sci. of Phil,, 1889

southern slope there is a forest of Pinus rigida which is being constantly encoached upon.

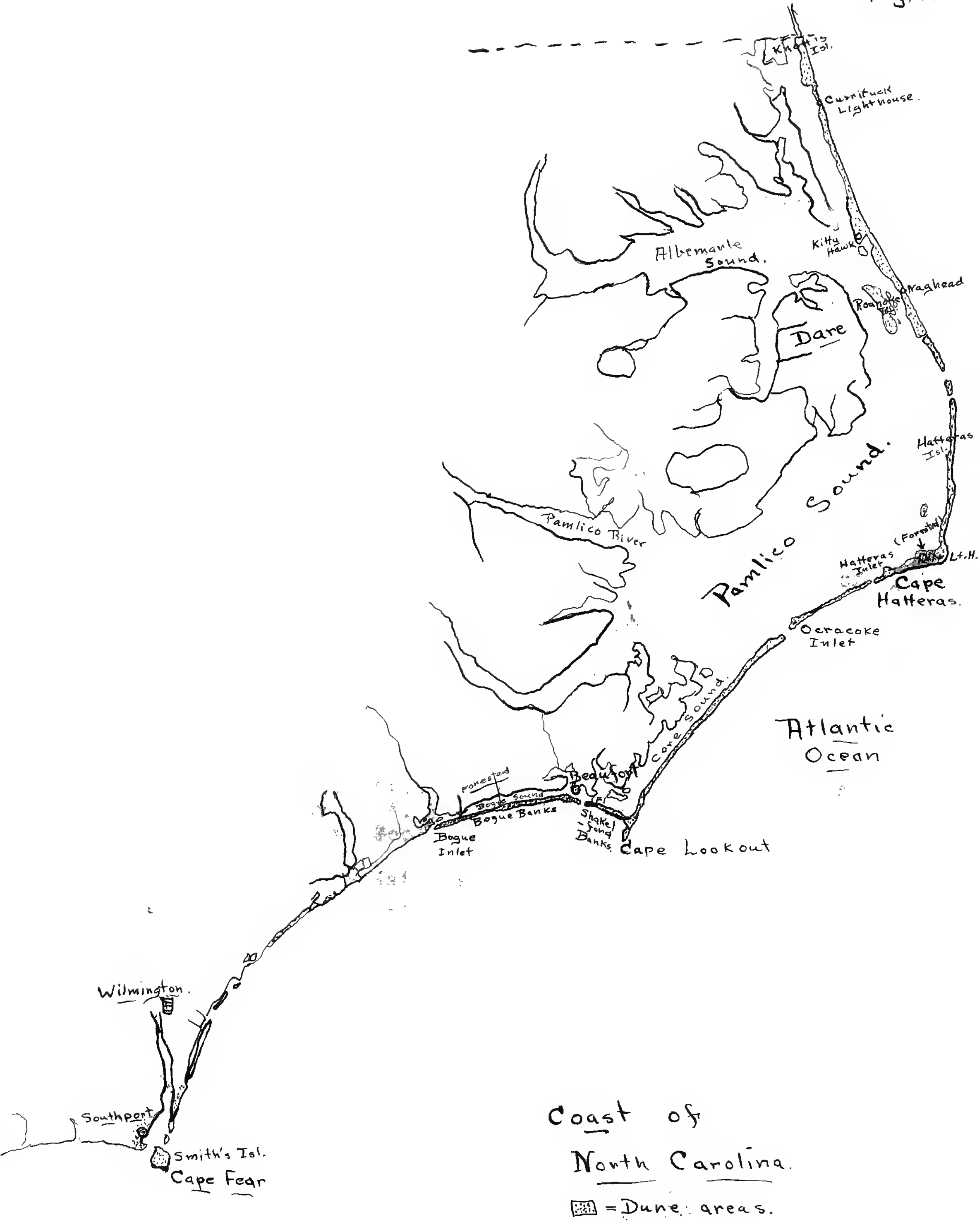
Indeed, at present, one may there see trees in no way surrounded or even endangered by sand. A few yards to the north there is the face of the advancing sand hill, where one finds pines in all stages of burial and with unknown numbers totally buried.

The force at work here is plain enough. The wind from the north and northeast drives the sand to the hill-top and when it reaches the crest, gravity carries it down the southern declivity. The forests are buried, killed, stripped of their foliage and the dune moves on covering new plant life. However, while the ground is being lost to the forest and to the hay makers in the south or west, there is a gain in the north. Here the marshes are filled and a second forest growth has started on them.

To one familiar with the dunes of Cape Cod, the absence of wild rose, blue berries, beach plums, etc. seems peculiar at Lewes. They illustrate further that we have near this city the same forces at work that devastated the "Landes" of France. These dunes and trees suggest the remedies that may be taken which restored those wastes to France. While Pinus pinaster (Soland), or maritime pine was used to make a seaward barrier, we here can safely depend upon Pinus rigida or the pitch pine which is growing at Lewes to safely accomplish this same result.

"Indeed from Massachusetts south to Lewes, here and there, in sight of the sea and on a most sandy soil this tree is flourishing, almost as well as it does on the rocky

Fig. 11.



Coast of

North Carolina.

▨ = Dune areas.

Follows page 44.

hillsides in the interior of Pennsylvania."

## Sand Dunes on the North Carolina Coast*.

This part of the North Carolina coast between Cape Hatteras and the wooded area, about 6 miles west of Beaufort Inlet is more or less typical of the whole North Carolina Coast.** The section described further is, however, the only part where protective measures need be taken at the present time.

### Damage by Shifting Sands

In this region there is considerable evidence of marked changes with incomparatively recent times. Within the memory of many inhabitants# the banks along the coast

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* Report on an examination of the sand banks along the North Carolina Coast by J. F. Bond, U.S. Forest Service Biennial Report of the State Geol. Sur. of North Carolina, 1907-08.

** Collier Cobb in the Nat. Geog. Mag. Vol. XVII, No. 6, 1906, "Where the Wind does its Work", makes the following statement :-

"The dunes are best adapted along the Currituck Banks from Virginia to the Kill Devil Hills. Hatteras Island was covered with forests in 1860 and with the removal of timber, dunes were formed which are at present filling in the shore of Pamlico Sound. The reforestation of this island would make the land a sub-tropical garden with early vegetation and game. The Bogue Bank forests grow down to the water's edge thus preventing the formation of sand dunes."

# Collier Cobb in the Nat. Geog. Mag. No. 19, 1908, p. 509: "Some Human Habitations" - gives in excellent idea of the character of the people of the banks and of these conditions under which they live.

were covered with forests. At present, however, the forests occur at only two points. Immediately west of Cape Hatteras are approximately 2500 acres covered principally with loblolly pine. Recent estimates show this stand to hold approximately 2000 M. b.f. This stand is only of medium quality. Near the western end of the Shackleford Banks are a few hundred acres of forest composed almost entirely of red juniper. Both of these forests are being exploited.

The entire area between these points is barren and unproductive. Only in one or two places where there are small villages is there any attempt at tillage. Sand more or less fixed in the form of dome shaped dunes extends from the ocean to the sounds. The damage here is complete and the improvement of the area as a whole is practically impossible.

There are two localities on the area where protective measures would prove a decided benefit. At the southeastern and southern part of the woodland near Cape Hatteras the blowing sand is rapidly encroaching upon and destroying the forest while at Beaufort Inlet the surface sand is being blown into Core Sound, and, through the destruction of the beach, the width of the inlet is perceptibly increasing. The problem of arresting the damage at these two points is discussed in detail below.

## Cape Hatteras Forest

Along the entire southern and western edges of the forest west of Cape Hatteras a considerable area of woodland is being buried and destroyed by blowing sand. As stated

above this timber is valuable and in addition the occurrence of the forest makes this locality by far the most desirable residential section of the banks. It is simply a question of a rather limited time, however, when the encroachment of shifting sands, together with destructive logging will complete the permanent denudation of the area.

The greatest difficulty to be encountered in the treatment of this area is that the land is private property and therefore can scarcely be controlled by legislative action. Apparently nothing can be done, except in an advisory manner to prevent further exploitation. Fortunately, however, the logging operations were begun at the sound side of the forest and farthest remote from the area being encroached upon by the sand and hence the cut over area will have a chance to reforest naturally before the removal of the timber immediately in the lea of the approaching sand dune. The large amount of loblolly pine in the stand makes reproduction certain with a minimum of protection. It is certain however, that the greatest factor in the destruction of the original stand has been careless lumbering.

The destruction resulting from logging has been made permanent by unrestricted grazing. Cattle, sheep, goats and hogs have had free range and the damage from these sources can not be over-estimated. Hogs are the greatest menace, and a single hog, practically valueless, will root out large areas of sand binding grasses along the beach. Cattle and sheep complete the destruction by eating the roots of the up-rooted grass. The sand thus liberated is carried

away by the wind and a "blow-out" results. This "blow-out" constantly enlarges until the damage becomes general and large areas are affected. The total value of the stock between Cape Hatteras and Hatteras Inlet is no more than $1000. The stock is all inbred and the hogs are unfit for consumption as meat as they feed on carrion fish.

It is strongly recommended that such stock be eliminated from this area by act of Legislature. Without such protection all measures for the control of the shifting sand will be useless. At present the destruction is so great that live oak reproduction which is naturally abundant is missing and even pine reproduction is very seriously damaged.

The sand-dune area which is encroaching on the forest lies to the south and east of the woodland. Beginning at a point two miles east of Creed's Hill Life Saving Station it extends westward four and one-half miles and beyond the wooded area where the sand extends entirely across the banks to the sound. A description of this area and certain recommendations appear below.

## Cape Hatteras Sand Dune Area

The moving sand of the dune area between the forest and the oceas has already covered up and destroyed the growth for about one-half mile inland. At the western end of the dune the sand gradually slopes into a low, marshy area which extends to the Durant's Life Saving Station, where a small body of live-oak occurs. To the south of this woodland is a long, narrow sand dune and to the west a low, wash-flat

extends to Hatteras Inlet where there are a few mound like dunes near the beach.

It is only the dunes south and west of the Cape Hatteras forest which are further discussed since the dunes to the west can do practically no further damage. Over this area the sand is constantly moving in a northeast direction. The surface is practically bare of vegetation and such vegetation as does spring up is immediately destroyed by the stock.

The direction of the movement of the dunes is undoubtedly influenced by the forest growth which shelters the area from the northerly winds. From the south the winds have interrupted sweep, and, in consequence, the sand is carried by these winds in a northerly direction. The prevailing winds during the different seasons have a greater or less influence on the direction taken by the dunes. In summer the dry sands are carried by the prevailing southerly winds while in winter the moist sand is not so easily carried by the prevailing northerly winds. The result is that even where the winds have full sweep in both directions the general movement of the dunes is toward the north.

At the northern end of the sand the dunes terminate abruptly at the edge of the woods. Here there is a high dune rising gradually to a height of about 25 feet. To the leeward the slope of the dune is fully 35° which seems to be as steep as sand will remain at rest.

The advance of these dunes is relatively rapid as there are numerous living tops of trees protruding from the sand considerably to the windward of the crest of the leeward

dune.

To control and fix these dunes will require careful treatment and an expense entirely disproportionate to the value of the reclaimed land and the forest lands in the lee. So long as present conditions in regard to law and ownership of the area exist, protective measures are impossible. In the addition to the enactment of stock laws as recommended above, it is recommended that the state purchase a strip of the forest land in the lee of the dunes not less than 500 and preferably 1000 feet wide and extending along the whole forested area. When this has been done the active measures looking to the control of the sands may be put into effect.

## The Fixation of the Sands

The permanent reclamation of the sand waste depends upon two things.

1. Since the source of supply of the sand is inexhaustible, a barrier must be provided near the beach to prevent new-supplies of sand which are brought up by the surf from being blown inland.

2. The loose moving sand in the lee of this barrier must be permanently fixed by growing forests.

The success of all work relative to the satisfactory growth of the trees and consequent binding of the sand depends upon the barrier and past experience has established that this barrier is most satisfactory, if it consists of a littoral dune of proper height built up by sand which is arrested by means of mechanical obstructions and held in place by suitable sand-binding grasses. It should be built

up parallel to the shore line and not nearer than 100 feet to high water mark.

When the work of fixation is complete, the entire area, with the exception of the strip between the barrier dune and the shore line, will be covered by a forest. The strip to the windward of the barrier must be held in place by the planting of grass. When the forest has been established it should be cared for according to usual forest practice.

It will be impossible to establish a forest directly upon the drifting sand either by the sowing the seed or by setting out young trees, since the blowing sand either uncovers the seed or buries it too toodeeply, while in the case of planted trees the sand cuts the leaves and bark or buries the plant. It will therefore be necessary to hold the sand in place by some mechanical covering until the trees have developed and form a natural cover.

The work of fixation is thus divided into two stages. 1. Preliminary, holding the sand in place, (2) Permanent, establishing a forest. Upon the coast strip the work never proceeds beyond the first stage and the maintenance of a grass cover will require constant care.

## The Coastal Strip and Barrier Dune

The coast strip and barrier dune should be handled in such a way that the surface of the strip may not jeopardize the stability of the dune. It is obvious that the first work is the proper formation of the dune. This is done by rapidly accumulating blowing sand so as to form a long ridge.

For this purpose palisade fences arranged in a double row six feet apart are used. Each fence should be made of inch boards 6" wide and 5' long, driven about 2' into the sand. The tops of the fences should be of equal height and the palings should be four inches apart. Such an arrangement of fences allows the wind to pass through but reduces its velocity and hence sand is deposited within and on both sides.

As the sand accumulates to the top of the fences, the palings should be raised, and, when the dune has reached a height of 30 feet, sea oats (Uniola paniculata) should be planted 3 feet apart, alternating in rows 3' apart, parallel to the crest of the dune. The grass should be planted on both sides of the dune and gradually extending to the windward until the dune attains a fairly permanent form with a gradual slope to the windward, while on the leeward side the slope should be approximately 30°. The successive steps in the formation of the barrier dune is shown in a series of diagrams in the appendix.

The barrier dune when completed, will protect the area in the lee but will require constant care to keep it in proper condition. Every precaution should be taken to prevent a break in the dune and if such occurs it must be repaired immediately since the wind will constantly enlarge such openings. A "break" may be repaired by the simple expedient of piling brush on the surface of the "blow-out" and, when the sand has filled into its former level, by replanting the grass as before. The main care should be to maintain a good grass cover over the dune and coast strip. When the grass has become

too thin in one place, plants needed should be taken from areas where it is thicker than necessary.

## Forestation

The area in the lee of the littoral dune must be planted in forest trees* to accomplish permanent fixation. Local conditions and geographical position of the area to be planted are such that proven methods developed in extensive work of this character in Europe may be adapted to this project.

It has been established that the most certain method of securing a forest cover on waste sand is by direct sowing of the seed, provided that suitable species** are available for use in the locality and also that the sand be temporarily fixed until the young trees are well established. Upon the formation of the barrier dunes the sands in the lee will be comparatively free from the action of the wind, since the dune will protect the area from the southerly winds, while the forest will serve as a windbreak to the north.

Loblolly pine#, a rapid growing species which produces valuable timber, grows throughout the banks. Although owing to the exposed situation, the quality of timber produced can not equal that of the forests of the mainland, this tree

*Collier Cobb in an article in the Nat. Geog. Mag. No. 17, 1906 entitled "Where the Wind does its Work", states : "The author planted loblolly on the back of a dune and covered the area with brush. The resulting reforestation of several acres was highly successful."

**Ashe, Bulletin #24, 1915.

# Ashe, N. Car. Geog. and Ec. Survey 1914, p. 145.

is by far the most desirable commercial species on the banks.

The proper method of sowing the seed can be determined only by experiment.

Two methods are suggested, the second to be used only when it has been clearly demonstrated that the first is not feasible. 1. Sowing the seed directly on the surface. 2. Sowing the seed after the sand has been temporarily fixed by a light covering of brush.

At the western end of the shore dune, on a strip 500 feet wide and extending from the dune to the forest, loblolly pine should be sown at the rate of 12 pounds per acre. The seed should be sown directly on the surface of the sand without any site preparation. Although there is good reason to count on favorable results there are disadvantages to it. Large amounts of seed will be destroyed by birds unless coated with red lead previous to sowing. Again some of the seed will be blown away and some buried too deeply under the sand. The efficiency of the littoral dune and forest in stopping the wind can only be determined by experiment. If the sweep of this wind can not be stopped direct sowing will be impossible. In this cast the ground should be strewn with brush laid in rows parallel to the barrier dune and the seed sown as before.

Such a method although more expensive than the first will insure success. The brush should be allowed to remain until the young trees are established and the year following the sowings should be removed in order not to interfere with the young seedling's growth.

Brush can be obtained from the nearby forest. Myrtle,

red bay, yaupon or similar material may be used. Slash collected after lumbering may also be trimmed for use.

The forest in the immediate lea of the sands, whose purchase has been recommended should be carefully conserved. Absolutely no cuttings should be permitted until a dune forest has been firmly established.

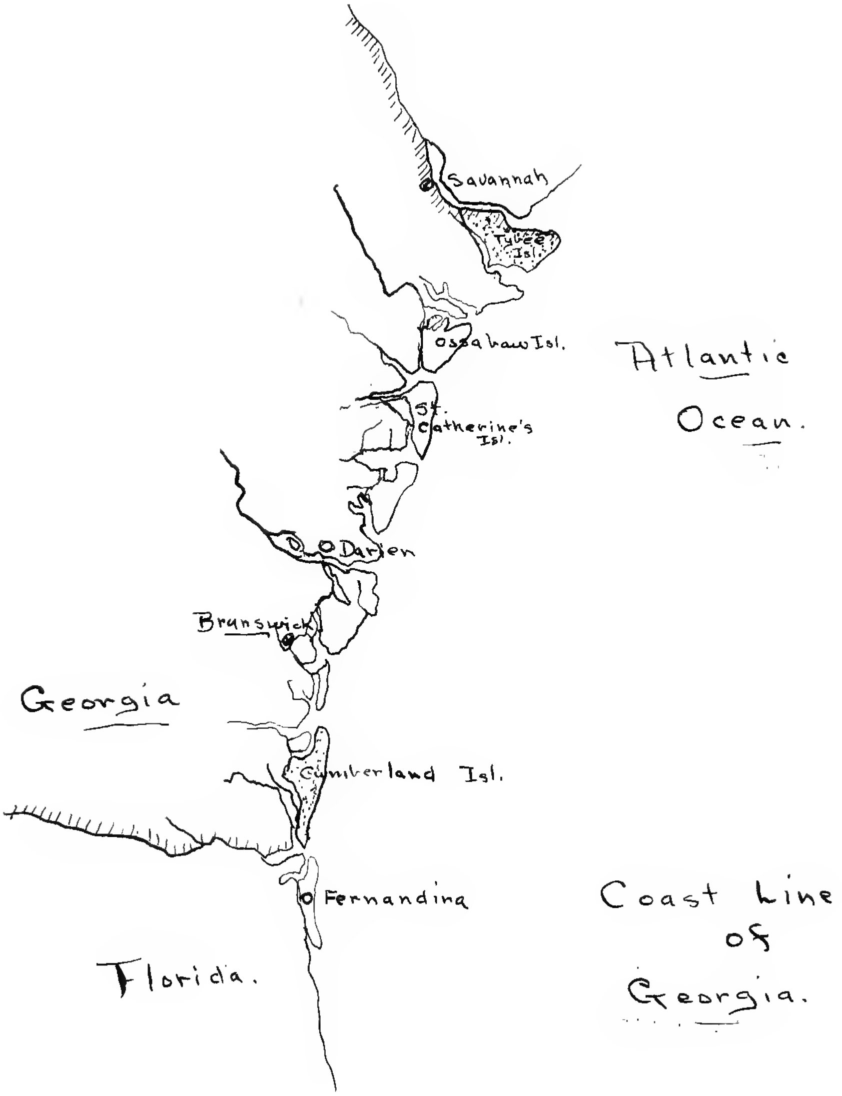
The expense of fixing the stand can only be approximated. There is no data to show the length of time needed to establish a barrier dune. The longer it takes to establish this dune the greater the cost. The cost of forestation however, can be approximated and will vary from $25 - $40 per acre depending upon the method used. Seed of loblolly pine are quoted at $4.00 per pound but could be obtained cheaper at contract prices. Material needed for palisade construction in building up the dune represents a cost of at least $2000. The cost of maintenance can not be predicted.

Grass planting on the coast strip and littoral dune will be expensive and cost at least $500 exclusive of maintenance. The entire cost of the work of fixation exclusive of any expense necessary in the acquisition of the lands, will reach at least $40,000.

## General Advisability of the Project

The work of fixing the sand will serve to accomplish the perpetuity of the only forest remaining on the banks above Beaufort Inlet;unless prompt measures are taken this forest will be destroyed. The lands will then become a waste similar to the rest of the bank. The cost of the work, however, is large and it is doubted if the property protected is worth the

Fig. 12.



Coast Line of Georgia.

Follows page 55.

cost.

Aside from the intrinsic value of the property, it must be considered that a considerable population will be seriously affected if this area is allowed to become a waste. These people are entitled to protection by the state and the preceding methods are the cheapest for satisfactory results.

If this work is undertaken it is suggested that the plans used in France be followed and that competent officials be placed in charge of this area and that they carry out in detail the general plans advocated.

## Georgia*

Owing to recent and still continuing submergence the coast is very irregular and contains many sea islands. These are sand covered and some of them exhibit sand dunes which, however, "Nowhere reach magnitude." The tree growth is chiefly composed of palmetto and live oaks.** Large accumulations of sand appear in the form of dunes 30 - 40 feet high on the east side of Flint River near Albany, Their maximum height above the river is about 100 feet. The sands were probably accumulated during the early Plustocene period and changes in conditions have prevented further growth. They are of no importance as they do not damage and are easily reforested.

## Florida

Sand dunes# and ridges are common especially along

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*U.S.G.S. Water supply paper #341 entitled "Underground water of the Coastal Plain of Ga." by L.W. Stephenson & J.O. Vealch,p.36.

**Bul.26 Prelim. Rept. on the Geol. of the Coastal Plain of Ga. by Veatch & Stephenson, p. 37.

# U.S.G.S. Water Supply Paper #319 Geol. & Underground waters of Fla. by G. C. Matson & Sam. Sanford, p/ 30.

the southern edge of the uplands, but few of them are more than a few feet in height. Wind blown sand probably occurs more wide spread than is shown by the surface topography. "The heavy precipitation, together with the abundant vegetation prevents the development of extensive dunes". "The notable feature of the dunes of southern Florida is their quiescence". These lands when cut of their timber are valuable for raising pine apples, and although bare the sands are but little moved by the prevailing winds.

In his letter, T. Wayland Vaughan mentions the dunes near Hobe Sound. On page 98 of this same bulletin there is an account of the dunes of this section.

"A noteworthy succession of dune ridges extends in an approximately north - northwest direction from two miles north of the dune on which stands Jupiter Lighthouse on the north side of Jupiter Inlet to and past Hobe Sound Station of the Florida East Coast Railway. Just beyond this the belt veers to the westward and dies away inside of three miles. Just back of the station the summit of the dune is 63 feet above sea level. Back of Jupiter lighthouse there is one 45 feet high near Palm Beach and other isolated dunes may be seen on the Coast Survey Maps near the east side of Lake Osbourne on Pine Island.

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* This bulletin gives an extended bibliography on sand dune formation, plant life, and control, besides that on general wind movement.

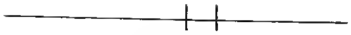


Fig 1

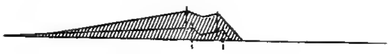


Fig. 3

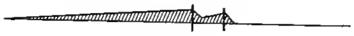


Fig. 2

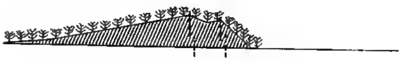


Fig. 4

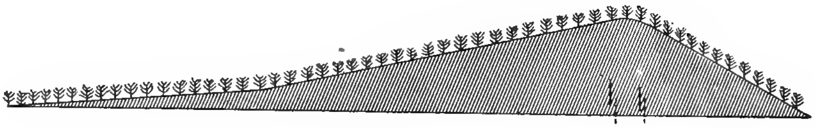


Fig. 5

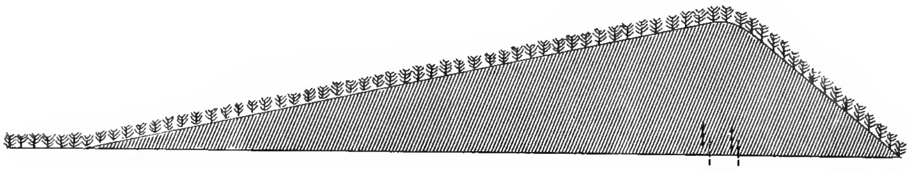
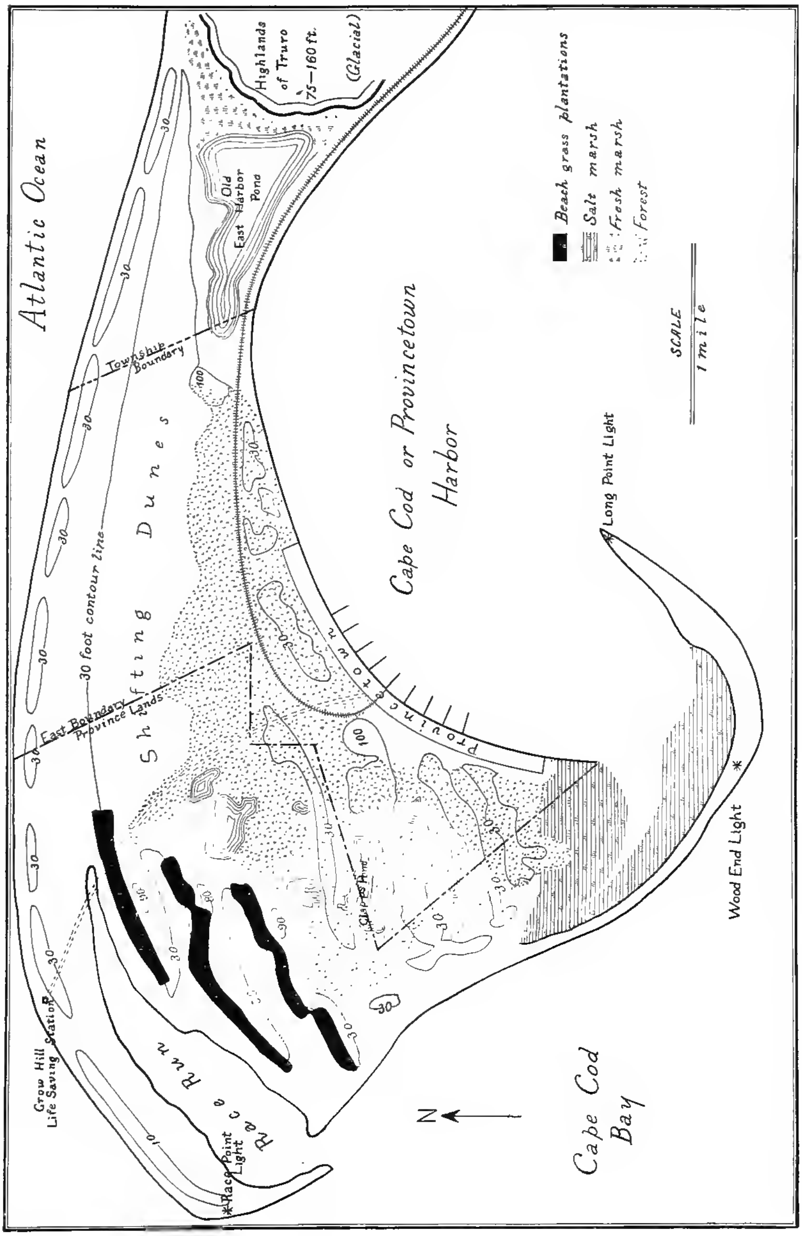


Fig. 6.

DIAGRAMS EXPLAINING PROGRESSIVE STEPS IN THE FORMATION OF BARRIER DUNE

When the dune has assumed the form illustrated by Fig. 4, grass is planted, and by extending the area planted towards the shore (to the left) the subsequent form of the dune is influenced.



MAP OF THE SAND AREAS INCLOSING CAPE COD HARBOR.

Plate 3

# PLATES.

## DESCRIPTION OF PLATES.

Plate I. (Frontispiece.) Map of the sand areas inclosing Cape Cod Harbor. The 30-foot contour lines indicate roughly the topography and general outlines of the seven dune ranges which constitute the larger portion of the sand areas surrounding the harbor. The outer three nonforested dune ranges have been covered with beach grass and are indicated in black.

Plate II. Fig. 1.—Beach grass forming protective beach ridge. The grass is shown to extend to within the limit of wave action during the winter storms. Its peculiar habit of sending out rootstocks when buried enables it to keep the ever-increasing sand deposits well covered. The gradual accumulations of sand incident to these depositing ridges form the ideal conditions for the thrifty growth of this grass. The beach ridge indicated has increased 20 feet in height during the past twenty years. The beach grass has been the chief factor in accumulating the sands necessary for the strengthening of this portion of the sand areas protecting the harbor. Fig. 2.—Beach grass, showing method of vegetative propagation. Beach grass is efficient in the natural reclamation processes owing to the method of rapid vegetative propagation from rootstocks, which enables scattered individuals to soon cover the drifting sands with a sufficient growth to prevent the sand movement.

Plate III. Fig. 1.—Set of beach grass suitable for transplanting. The set shows two nodes of the rootstock with attached rootlets. Two-year-old stock is most desirable for transplanting. The method of hand pulling is practiced throughout these areas. Fig. 2.—Transplanting beach grass. The gently sloping sand areas are covered with beach grass in the manner indicated. The brows of the hills are covered immediately with bayberry transplanted from the adjoining timbered areas. The steeper slopes are often reduced to an angle of 25 degrees or less before the planting is begun.

Plate IV. Fig. 1.—Lee slope of a sand dune showing the manner in which the advancing dune buries forests lying in its path. Fig. 2.—General view of the grass plantations, looking south. Native growth in foreground. In the background the transplanted beach-grass area adjoins the sands not yet covered. Bayberry bushes have been introduced upon the crests of the dunes. Before these areas were covered with the grass, the dunes were encroaching upon the forest and city shown in the distance.

Plate V. Fig. 1.—Bayberry bushes without grass protection. The presence of bushes alone is not sufficient to prevent the shifting of the sand. The large size of the sand grains is indicated in the foreground. Fig. 2.—Bayberry bushes with grass protection. The deterioration of the grass is evident but its duration is sufficient to enable the introduced woody growth to become self-protecting. The grass was planted in 1898 and the bayberry a year subsequently.

Plate VI. Fig. 1.—Wind erosion of nonprotected sand. The brush line in the center marks the eastward extension of the beach grass plantings of 1898. The amount of sand erosion by the wind since the grass was introduced is clearly indicated on the eroded sand areas at the left where it appears that at least 15 feet of sand have been removed. Fig. 2.—Protecting a road through the dunes. The brush lines, logs, and bushes form an efficient protection to the sides of the cut. The roadbed consists of brush overlaid with turf sods obtained from the neighboring forest.

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Plate 3

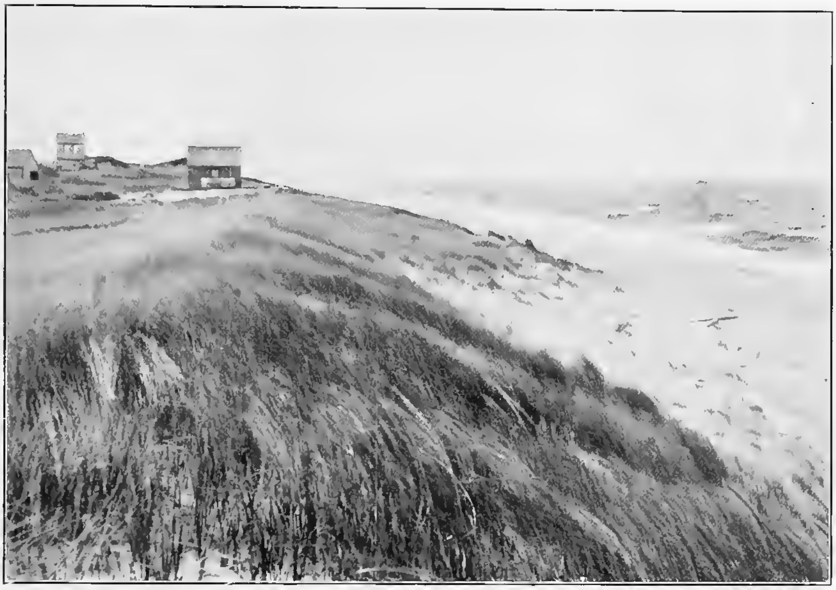


FIG. 1.—BEACH GRASS FORMING PROTECTIVE BEACH RIDGE.

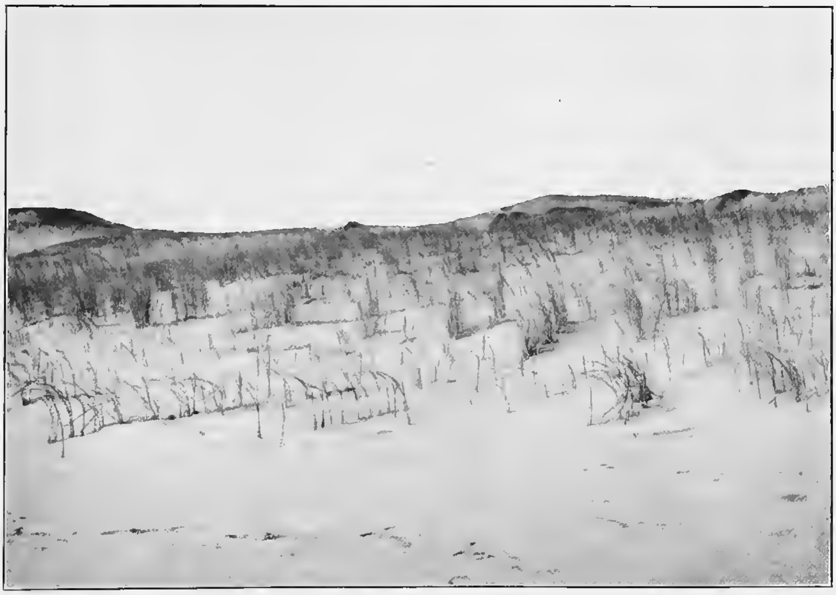


FIG. 2.—BEACH GRASS, SHOWING METHOD OF VEGETATIVE PROPAGATION.

Plate 3

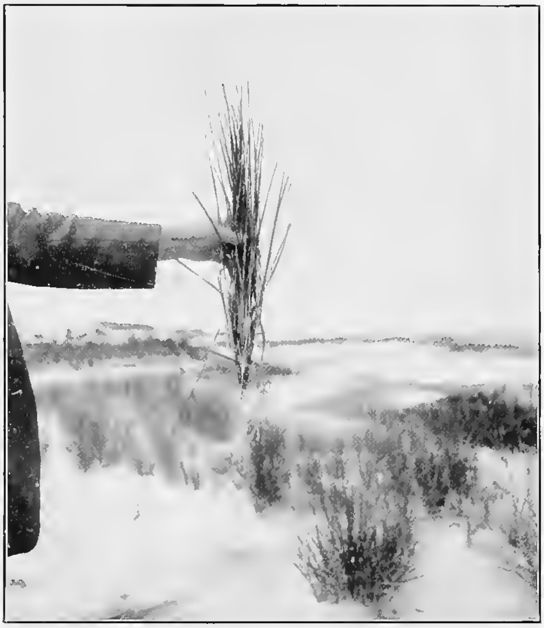


FIG. 1.—SET OF BEACH GRASS SUITABLE FOR TRANSPLANTING.

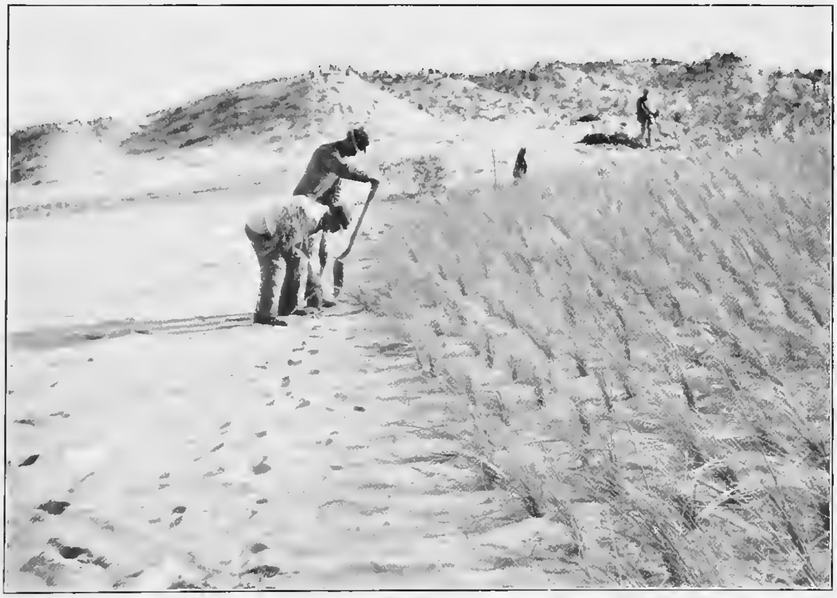


FIG. 2.—TRANSPLANTING BEACH GRASS.

Plate 3

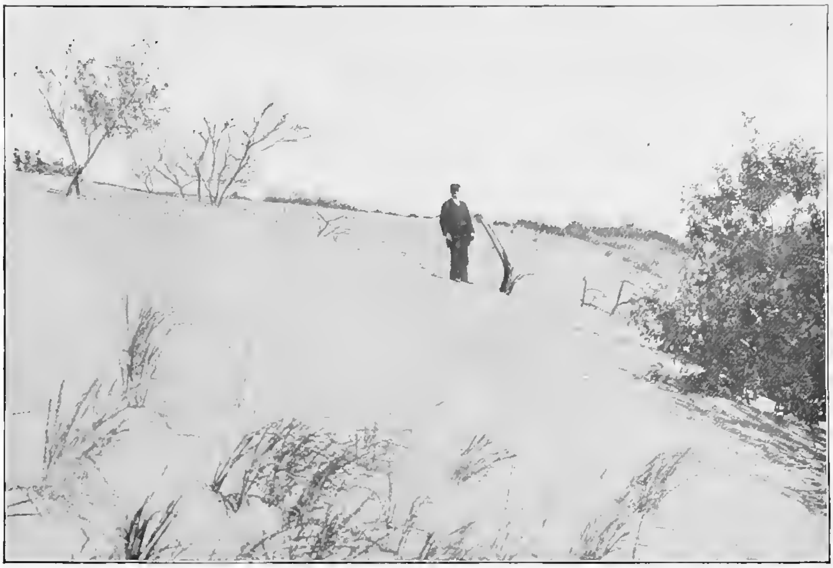


FIG. 1.—SAND DUNES BURYING FOREST.

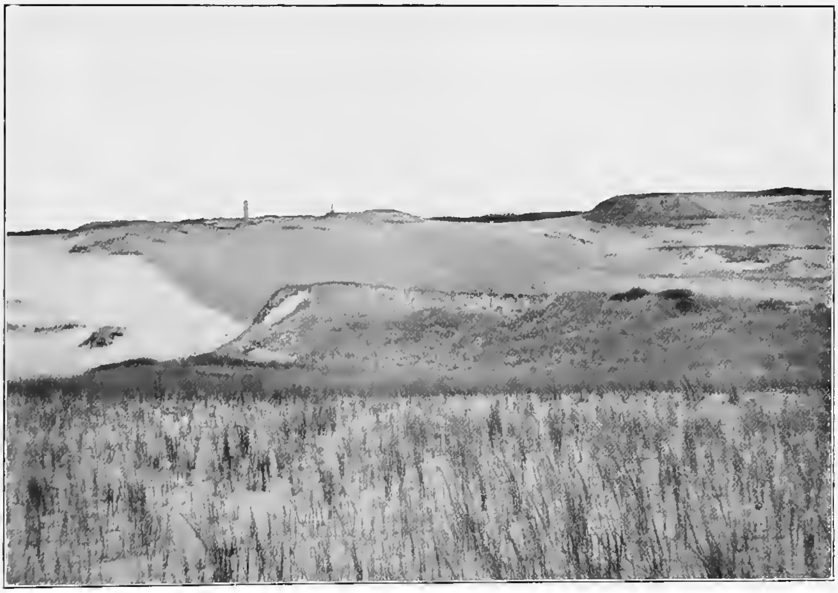


FIG. 2.—BEACH GRASS PLANTATIONS—GENERAL VIEW.

Plate 3.

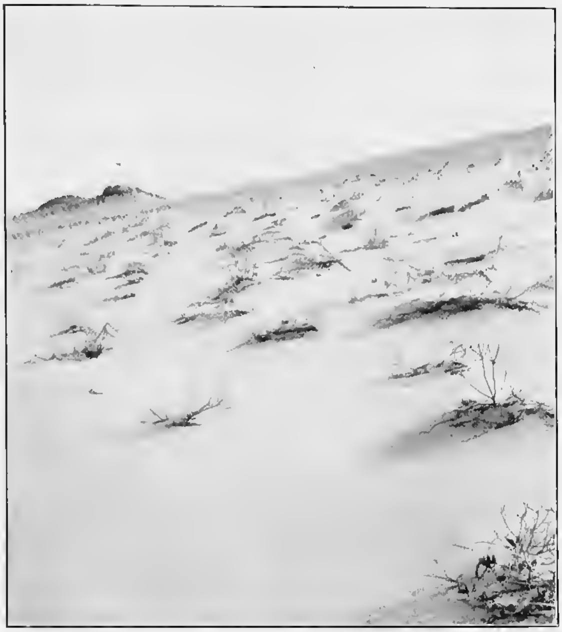


FIG. 1.—BAYBERRY BUSHES WITHOUT GRASS PROTECTION.

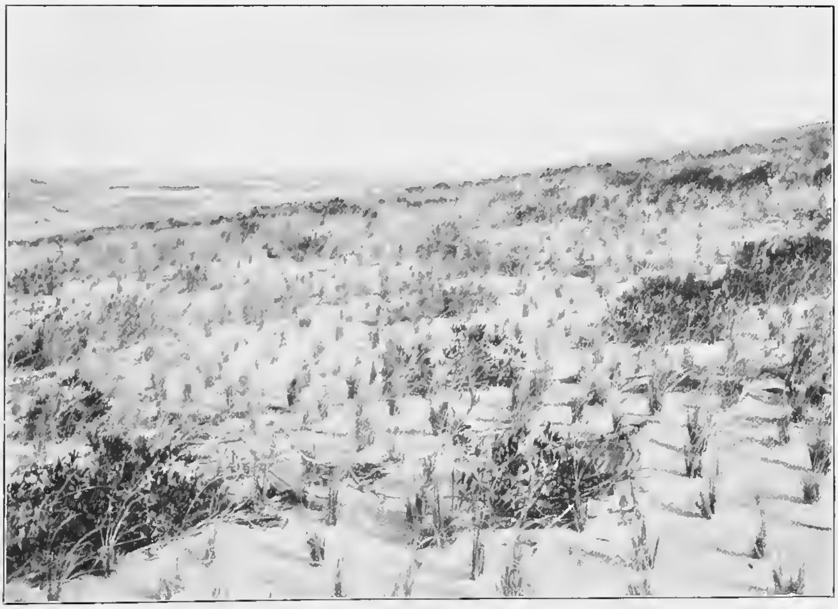


FIG. 2.—BAYBERRY BUSHES WITH GRASS PROTECTION.

Plate 3

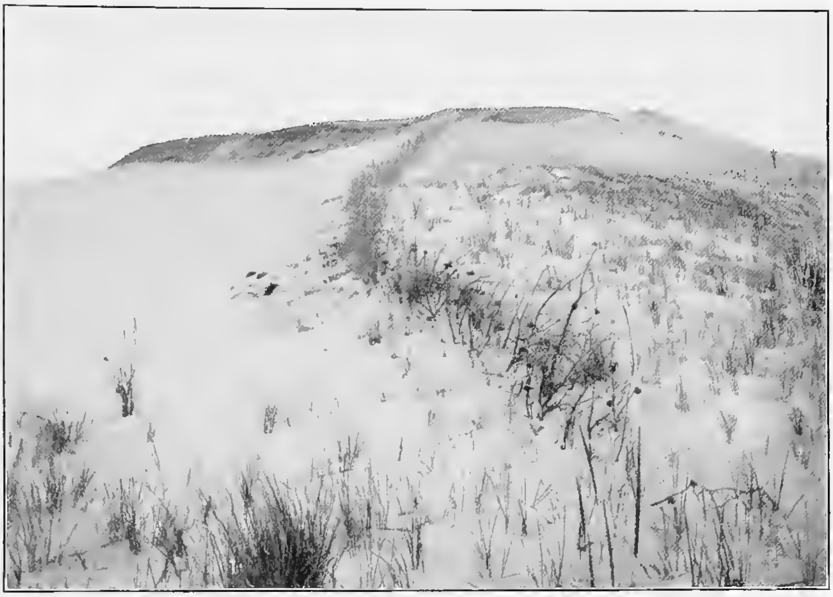


FIG. 1.—WIND EROSION OF NONPROTECTED SAND.

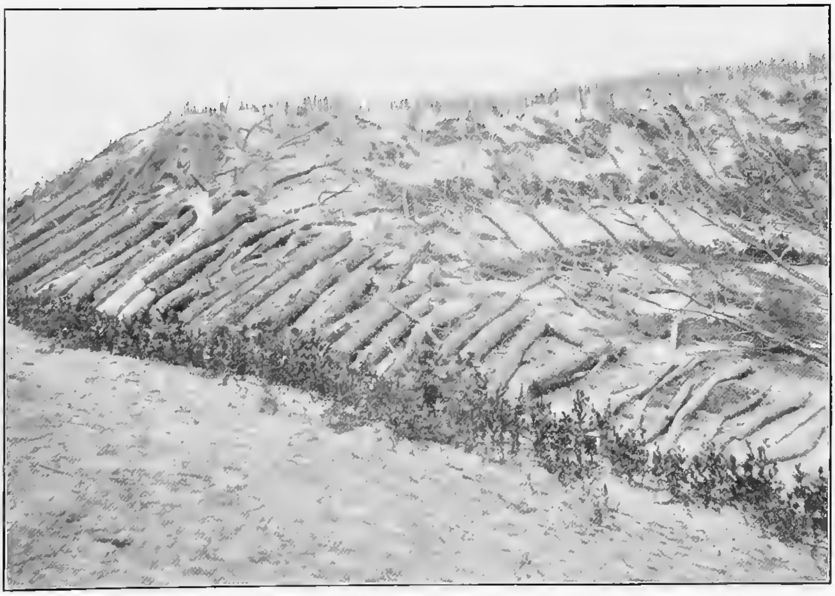


FIG. 2.—PROTECTING A ROAD THROUGH THE DUNES.

Plate 4.

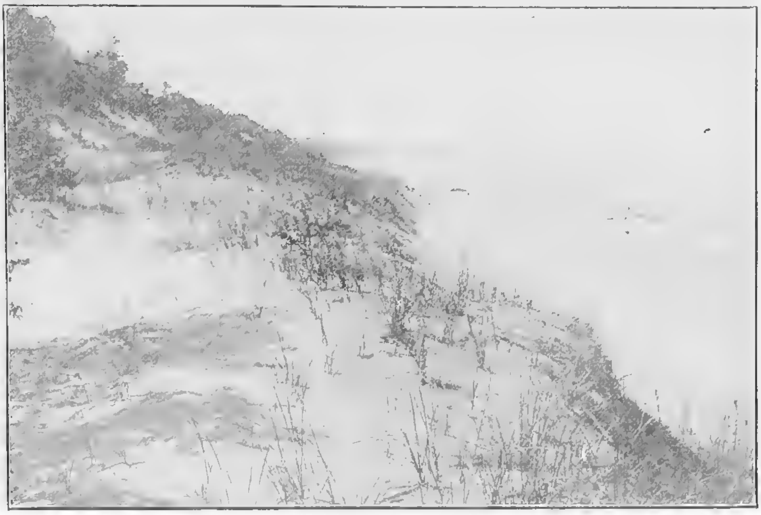


Fig. 3. The point of high water, or the point where the wind catches the sand. The bank of sand is here well planted to beach grass, and must be followed by tree planting. A disturbance or break in this grass cover, made by a foot trail or wagon wheels, is sufficient to make a wind path for the sand which may develop rapidly into a traveling dune.

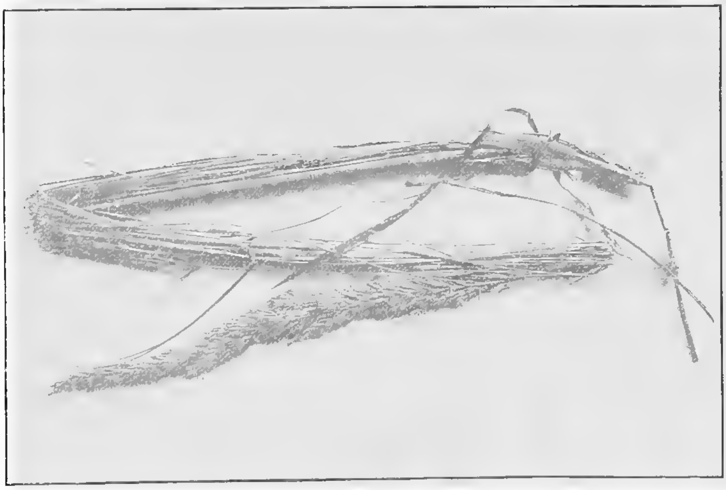


Fig. 4. Photograph of Ammophylla arenaria Link, commonly known as Marram or Beach Grass and considered to be the best of the sand binders.

Plate 5.

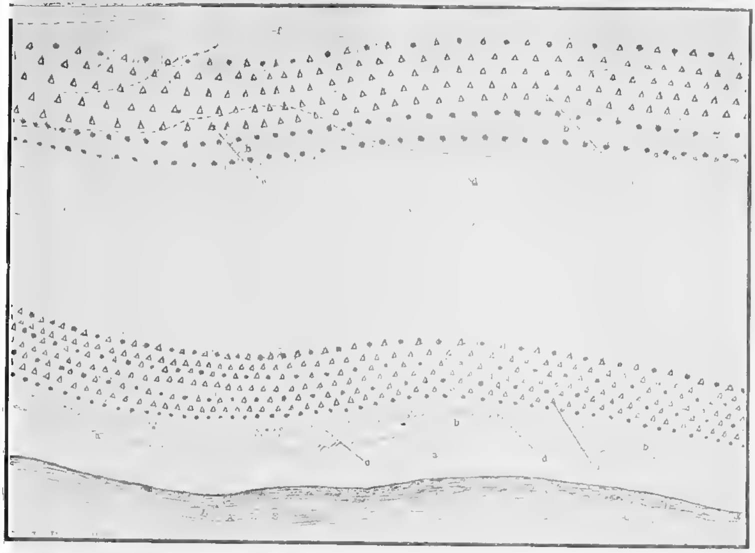


Fig. 15. Diagram of Shelter Belt Method.
a. Barrier of rubbish and waste.
b. Beach grass planting.
c. Willow cuttings.
d. Poplar cuttings, or rooted sets.
e. Conifer planting.
f. Contour lines.

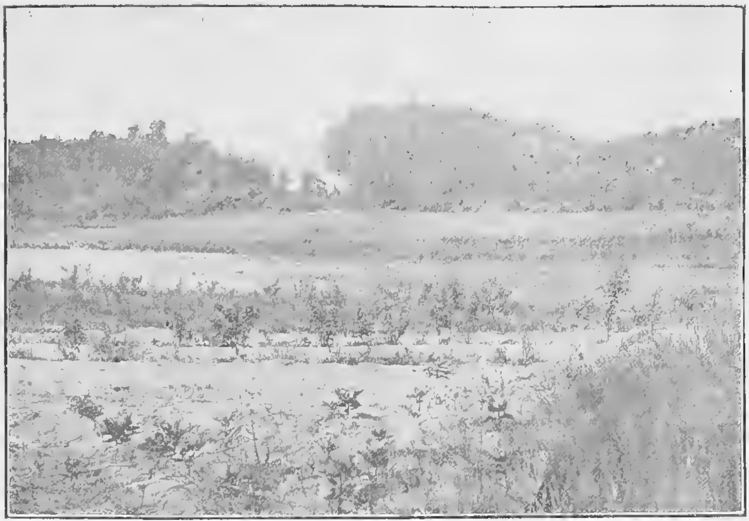
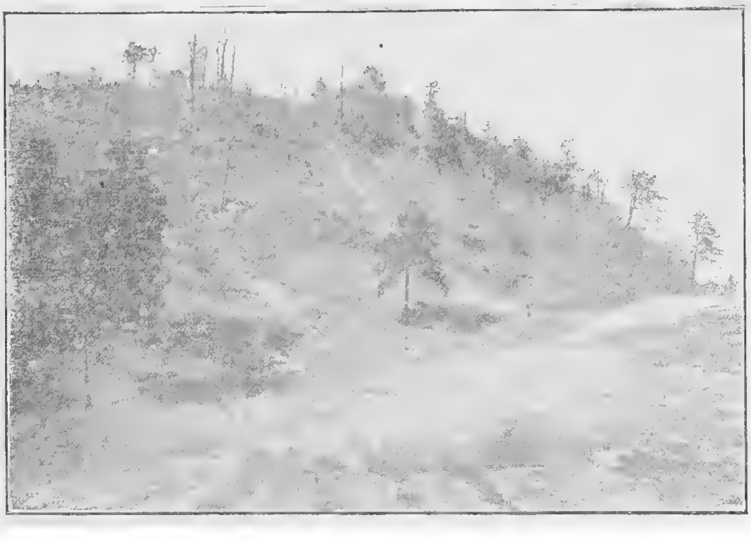


Fig. 5. Break over top of a wooded dune caused by a road which led from the water edge to the top. Wind soon caused the destruction here shown. This dune is burying an orchard.



Typical established dune with the cover breaking down.